AERONAUTICAL ENGINEERING REVIEW

OCTOBER 1950

MICROCASTINGS

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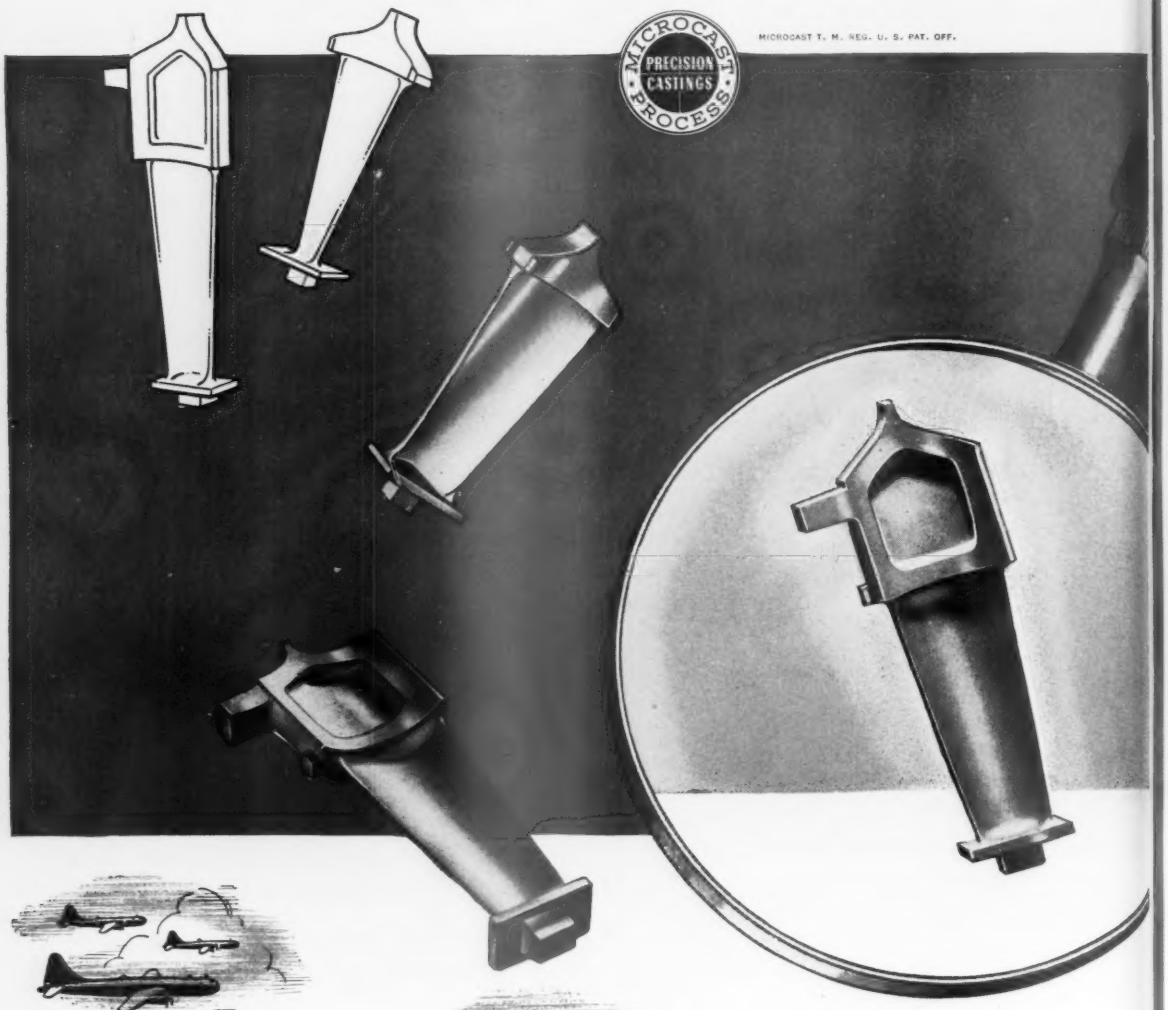

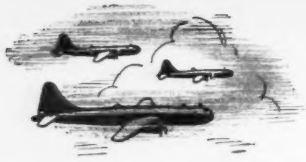

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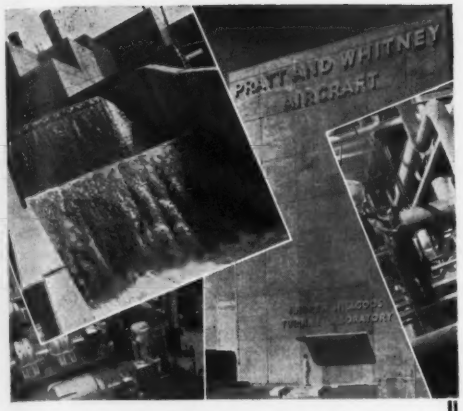

Cover—Andrew Willgoos Turbine Laboratory
(see page 7).

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I. A. S. News

A Record of People and Events of Interest to Institute Members

Robischon Appointed I.A.S. Western Manager

Aeronautical Consultant Replacing James L. Straight, Former Assistant Director of the Institute. Robischon Will Direct All Institute Activities in Western Region.

EARLY IN SEPTEMBER, ERNEST WILLIAM ROBISCHON assumed the duties of the Western Manager of the Institute of the Aeronautical Sciences Building, 7660 Beverly Blvd., Los Angeles 36, Calif., following the resignation of James L. Straight as Assistant Director of the Institute in residence in Los Angeles. Eminently qualified to fill this position, Mr. Robischon was selected from a group of candidates on the recommendation of the engineering heads of the Pacific Coast aircraft companies.

Mr. Robischon first became interested in aviation when as a lad of 6 years of age his father presented him with a model airplane. During his school days he began his well-known private aeronautical collection of books, paintings, airmail stamps, pamphlets, models, etc. It was his unusual library of aeronautical books which was responsible for his first position with California Institute of Technology as Aeronautical Librarian. He was later given other posts with CalTech such as: Assistant in Design and Construction of Aviation Research Equipment; Liaison and Consultant in connection with the Pacific Aeronautical Library, of which he was Founder and at one time Director; establisher, with the Director and Assistant Director, Aeronautical Department, of Durand Reprinting Company, a nonprofit publishing company; establisher of a Visual Education Program; and Assistant to the Director, Aeronautical Department.

Ernest William Robischon.

As a direct outgrowth of his work with CalTech, he was appointed a Consultant on the establishing of an agency in London known as Air Document Research Center, which was set up to organize and disseminate captured German Air Technical Research Information. This was followed by 2 years with T-2 Intelligence, Air Materiel Command Wright-Patterson Air Force Base, Ohio, where he acted as Consultant in the establishment in the United States of the Air Documents Division in order to further the activities begun in London.

In 1948, Mr. Robischon went with Cessna Aircraft Company as Methods Engineer, and in 1949 he became associated with Beech Aircraft Corporation in the same capacity. He is a private pilot and is Executive Secretary of the Durand Reprinting Committee. For a time, he was Associate Editor of *Aerosphere*.

It was Major Reuben H. Fleet who, during his tenure of office in 1944 as President of the Institute of the Aeronautical Sciences, first sparked the project that ultimately took the form of the I.A.S. Western Headquarters. The purpose of this branch, in keeping with the basic mission of the Institute, is to provide the maximum possible means for the interchange of current technical information among the Institute members in all parts of the United States. Begun late in 1948 and completed just in time for the 1949 Annual Summer Meeting, the building has proved to be an ideal, specially equipped meeting place devoted exclusively to the practioners of the many sciences and technologies that contribute to aviation.

In January, 1947, Mr. Straight took over the duties as Manager, Western Region, with headquarters in Los Angeles. In January, 1949, he was appointed Assistant Director, empowered to represent and act for the Director in all phases of I.A.S. activity on the West Coast.

Primary among the functions of the Western Manager are the coordination of the facilities and services of the Institute with the requirements of members in that area and the maintenance of close liaison between the western activities and the National Headquarters.

James L. Straight.

I.A.S. Cooperates with Aircraft Industry

EXIGENCIES OF THE CURRENT WORLD CRISIS have brought about the turning over of the I.A.S. building in San Diego to Consolidated Vultee Aircraft Corporation for the duration of the emergency.

Some time ago, Convair had leased the area immediately to the rear of the San Diego building for the purposes of storage and testing. When the present expansion program at Convair was initiated, an urgent requirement for additional space developed and the subject of leasing the entire area was broached. After a discussion with Major Reuben H. Fleet, who in 1944 (as National President) first perceived the need of adequate housing for the Institute in the San Diego area and who raised funds for the New York, Los Angeles, and San Diego buildings; with the donors, LaMott T. Cohu, H. I. Mandolf, Emund T. Price, Fred H. Rohr, and T. Claude Ryan; and with the members and officers of the San Diego Section, the idea was unanimously approved and a lease subsequently drawn up.

Last August, Convair took possession of the building with the proviso that it be returned to the Institute as soon as possible after the conclusion of the emergency. All remuneration realized from the rental of this property will be used for the furtherance of the I.A.S. aims.

The plans and specifications for the San Diego building resulted in a beautiful and economical structure (see photo above) located on Harbor Drive, which skirts the San Diego harbor from Point Loma to Palm City. The style of architecture that was employed is in harmony with the city's proposed development of this area.

Since the dedication of the building on the evening of April 29, 1949, the members and officers of the San Diego Section have devoted themselves untiringly to the time-consuming task of placing the San Diego building on a self-sustaining basis. By dint of perseverance, the building began to be used by other organizations as their meeting place, and this past June the members and officers saw their building operating "in the black" for the first time in its existence. It was a hard job well done, and we wish to take this opportunity to offer our congratulations to these persons for the ultimate accomplishment of their goal.

Taken at the time of the dedication of the San Diego building, this shows the then-incumbent I.A.S. San Diego Section Officers and Committee Chairman active in the building program *(left to right):* Ernest G. Stout, National Councilor; E. P. Rhodes, Building Committee Chairman; W. T. Immenschuh, Corresponding Secretary; Jack Mason, Past Chairman of the Building Committee and Chairman of the Dedication Committee; K. R. Jackman, Building Management Committee Chairman; Frank L. Fink, San Diego Section Chairman; holding the golden key to the building, B. T. Salmon, Past-Chairman; Dwight Bennett, Vice-Chairman; Joel Whitney, Member of the Building Committee and the Contributors Committee; Ralph Bayless, Treasurer; James L. Straight, I.A.S. Assistant Director; and Ralph Shick, Recording Secretary.

Dedication Ceremonies: *H. M. Horner, President, United Aircraft Corporation, "emcees" the dedication of the Andrew Willgoos Turbine Laboratory to the memory of Pratt & Whitney's Chief Engineer from 1925 to 1949.*

The Willgoos Turbine Laboratory

The largest privately financed jet-engine research laboratory in the world was dedicated on July 26 by Pratt & Whitney Aircraft Division, United Aircraft Corporation, to the memory of Andrew Van Dean Willgoos, its Chief Engineer from its founding in 1925 until his death on March 1, 1949. The laboratory is called The Andrew Willgoos Turbine Laboratory and is scheduled to go into full-scale operations immediately in support of Pratt & Whitney Aircraft's extensive jet-engine development program.

An oil portrait of Andy Willgoos was unveiled in the laboratory lobby above a bronze plaque bearing a citation that reads in part:

"Every Pratt & Whitney engine developed during those twenty-three years bore the unmistakable stamp of his genius as an engineer. His was a large personal share in the creation of the aircraft power plants which contributed so importantly to victory in World War II."

▸ **The Dedication**—In the dedication speech, delivered by Leonard S. Hobbs, Vice-President for Engineering, United Aircraft Corporation, it was stated: "The dedication of this laboratory to Andrew Van Dean Willgoos is a recognition of the talents and contributions of the designer of Pratt & Whitney power plants. Every engine that has ever carried the Pratt & Whitney name plate was Andrew Willgoos in substance and in impression. . . . . It is also Andrew Van Dean Willgoos, the engineer, to whom tribute is being paid and through him to all engineers—those who have gone before and those who will come after. . . . . Because of his other accomplishments, it is not always remembered that, from the founding of the company, Andrew Willgoos laid down the rules that governed the degree of material excellence of every engine delivered. . . . . It is fitting, therefore, that this laboratory be dedicated to Andrew Van Dean Willgoos, designer and engineer and, above all, the man whose humaneness, character, and fineness shine just as brightly and are just as real as when he was helping to plan it."

▸ **The Laboratory**—The Andrew Willgoos Turbine Laboratory was built at a cost of $12,000,000. It is a huge concrete structure, six stories high, 400 ft. long, and windowless. When operating at capacity, the laboratory will be able to generate up to 80,000 hp. for testing turbine engines and their components. It also has an air-pumping capacity of 25,000 hp.—more than double the air-pumping power needed to ventilate both the Holland and Midtown tunnels in New York City. Ground was broken at the Connecticut River site near Hartford in March, 1947, and work on the main laboratory began in June, 1948.

The Willgoos Laboratory is operated by the Pratt & Whitney Engineering Department under Wright A. Parkins, Engineering Manager, and B. A. Schmickrath, Chief, Experimental Laboratories. It has four test cells in which engines and engine components are to be tested. Two cells are located in each end of the building, which extends east and west. The two largest cells, 135 ft. long, are used to test compressors, turbines, and entire turbojet or turboprop engines. The cell used for the compressor test utilizes a self-contained 21,500-hp. electric driving motor to provide the huge power output needed for compressor test. In the adjacent chamber, used to test the jet engines or their turbine components, a 10,000-hp. dynamometer is in use.

The smaller pair of cells on the west end of the laboratory are used for testing burner components or complete jet engines. Pipes winding in a complicated pattern under the grating that serves as a test-chamber floor bring in cold, dense or thin air in varying intensities to the engine or engine parts to simulate flight conditions in varied temperatures and altitudes. All four test chambers are constructed to receive this service.

▸ **Power Equipment**—The heart of the Willgoos Laboratory is the service equipment section. Four boilers, originally built for Navy cruisers, stand in line on the service floor near four turbogenerators from war-surplus destroyer escorts. The four generators have a total output of 18,000 kw.—more than enough to supply a city of 150,000 population with light and power. On the same floor, additional equipment is installed, including ex-

(*Continued on page 8*)

Petroleum Research Laboratories

The Beacon Laboratories, located near Beacon, N.Y., are the main research laboratories of The Texas Company. A staff of over 800 persons is divided into three branches—Research, Technical Service, and Plant Service. The Research Branch, as the name implies, conducts the research; the Technical Service Branch acts as the information bureau for the company; and the Plant Service Branch provides clerical and craft forces to support the work of the other two branches.

The Research Branch, itself, is composed of eight components—analytical, engineering, grease, physical, chemical, fuels development, lubricants, and synthetic fuels.

▸ **Aviation Fuel**—Work is under way in the gas-turbine combustion laboratory to define those phases of the combustion problem which are primarily fuel problems (which could be solved by altering fuel properties) and those that are mixtures of design and fuel problems (inherently design problems). The effects of fuel composition on combustion in various types of gas-turbine burners are being thoroughly studied. Studies of combustion in steady-flow systems are being made in a ram-jet setup under contract with the Office of Naval Research.

Both fuels and lubricants are tested in the "Cooperative Universal Engine." This is a special crankcase on which is mounted one cylinder from a full-scale aircraft engine. Test conditions such as speed, cylinder-head temperatures, fuel-air ratio, and manifold pressure can be varied independently over the full usable range of engine flight conditions to study the antiknock behavior of fuels. The test unit can be operated to simulate complete flights—i.e., take-off, climb, cruise, and approach—and lubricants can be rated on the basis of piston varnish, combustion-chamber deposits, piston-ring wear, valve and valve-guide performance, valve burning, and bearing corrosion.

Cooperative programs have been conducted with engine manufacturers to develop the fuel requirements of new-type engines, including gas turbines, and experimental fuels have been available for these purposes.

▸ **Aircraft Engine Oils**—A Continental four-cylinder engine is used for oil testing. An interesting feature of this setup is the fact that each cylinder can be run at a different temperature from the other three cylinders. In effect, four tests (each at a different temperature) can be run simultaneously. The temperature of each cylinder is controlled by servomotors that operate shutters in the cooling air streams.

Complete multicylinder full-scale engine tests are also conducted under contract by Pratt & Whitney on an engine owned by The Texas Company. The tests are run in cycles simulating typical air-line flight schedules, and all phases of engine performance are carefully checked.

A program has been initiated to check the operation of jet-engine bearings with low-viscosity oils.

▸ **Aircraft Gear Oils and Greases**—The high-speed gear tester uses aircraft gears at speeds up to 16,000 r.p.m. and tooth loads up to 1,500 lbs. A load equivalent to 690 hp. can be applied to mating teeth on the driving and driven gear. This unit is used to investigate the effects of lubricants, tooth face and form, material, surface finish, speed, and temperature on gear operation. Current emphasis is on the lubrication of high-speed turboprop engine gears.

A "High Temperature Grease-Test" checks the performance of greases at 300°F. and higher in ball bearings operating at 10,000 r.p.m. The test is run in 24-hour cycles until failure is indicated by noticeable noise or roughness in turning when checked by hand. These greases are necessary for applications such as generator and magneto bearings and are typified by Texaco High-Temp. Greases for extremely high-speed use are performance-tested at 36,000 r.p.m. and are used in automatic-pilot and gyroscope installations.

Aviation Fuels: *One of the largest test installations at The Texas Company's Beacon Laboratories is the gas-turbine combustion laboratory, where compressors driven by 500-hp. motors provide air for single-burner studies over a wide range of simulated conditions.*

Willgoos Laboratory

(*Continued from page 7*)

hausters, for simulating conditions of altitude in the test chambers; compressors, which supply air for the tests; and a ram blower, which can supply an airflow equivalent to a speed of 550 m.p.h. Refrigeration and other auxiliary equipment are housed on the service floor.

Operations of the laboratory demand a huge supply of water. Through a pipe 6 ft. in diameter and 190 ft. long, the laboratory takes in water from the Connecticut River at the rate of 120,000 gal. per min. That rate of flow is about six times the normal consumption of the city of Hartford. The water serves to cool the fiery exhaust gases rushing from test stands and also to service the eleven steam-turbine condensers in the laboratory. A trifle warmer, but otherwise unaffected by its part in jet testing, the water cascades back into the Connecticut River by way of a concrete sluiceway.

More than $300,000 was spent to muffle the roaring sound that is a natural by-product of turbine-engine testing. The soundproofing method employed utilized precast concrete sound-absorbent materials combined with an underground labyrinth of reinforced concrete that helps dissipate the sound. When the exhaust gases reach the end of the labyrinth, they are fed into large concrete expansion chambers that further lower the noise level. From these chambers the gases, much cooler and calmer, hiss

out through slots in concrete. Thus, the roar of the jet engine is reduced to the mild hissing sound of steam.

Heat damage to pipes and other parts of the laboratory is prevented by feeding the hot, high-velocity gases through a water spray as they emerge from the test operation. This reduces the temperature about 1,000° before the exhaust gases hit the soundproofing system.

Companies Receive Letters of Intent

The Air Force has issued letters of intent relative to the expansion program to the following major companies: Allison Division, General Motors Corporation; Bell Aircraft Corporation; Boeing Airplane Company; Consolidated Vultee Aircraft Corporation; Wright Aeronautical Corporation Division, Curtiss-Wright Corporation; Douglas Aircraft Company, Inc.; Fairchild Engine and Airplane Corporation; General Electric Company; Lockheed Aircraft Corporation; North American Aviation, Inc.; Northrop Aircraft, Inc.; Piasecki Helicopter Corporation; Republic Aviation Corporation; and United Aircraft Corporation.

Flight Safety Foundation Moves to I.A.S. Building

Flight Safety Foundation, Inc., of which Jerome Lederer, F.I.A.S., is President, moved last July to new quarters. They are now located on the ground floor of the I.A.S. Building, 2 E. 64th St., New York 21.

A.S.M.E. Schedules 1951 Meetings

The American Society of Mechanical Engineers has announced the following schedule for the 1951 meetings: Spring Meeting, Atlanta, Ga., April 2–5; Semi-Annual Meeting, Toronto, Canada, June 11–15; Fall Meeting, Minneapolis, Minn., September 25–28; and Annual Meeting, Atlantic City, N.J., November 25–30.

NEW POST

Colonel Robert J. Benford, U.S.A.F. Medical Service (M.), was recently assigned as Surgeon, U.S.A.F. Research and Development Command, Washington, D.C. Colonel Benford was graduated from Creighton University, Omaha, Neb., in 1928. He received the degree of Bachelor of Science from the University of Nebraska in 1932 and in 1934 the degree of Doctor of Medicine. Before assuming his new duties, Colonel Benford was Chief, Engineering Development Division, Armed Forces Medical Procurement Agency, Fort Totten, N.Y. He is a member of the Executive Council, Aero Medical Association, and is a member of the Editorial Advisory Board, "Journal of Aviation Medicine."

News of Members

▸ **William A. M. Burden,** Member, Benefactor, and I.A.S. Past-President, donated the sum of $10,000 for the continued expansion of the Aviation Collection by the Baker Library of the Harvard Business School. This collection includes the documentation of source materials on the story of the American aviation industry.

▸ **Walter H. Dickman** (A.M.), Chief Sales Engineer, Mineola Aircraft Engineering Company, announces the acquisition by his company of the complete hardware inventory of Viking Air Service, Inc., Astoria, N.Y.

▸ **Henry Philip Folland** (F.), Managing Director, Folland Aircraft, Ltd., England, was appointed an officer in the Civil Division, the Most Excellent Order of the British Empire.

▸ **Dr. V. M. Ghatage** (M.), Chief Designer, Hindustan Aircraft, Ltd., India, is a Vice-President of The Aeronautical Society of India.

▸ **Dr. W. Randolph Lovelace, II** (F.), Chairman, Aviation Medicine Panel, Security Advisory Board to the Commanding General, Air Force, departed from LaGuardia Field last August for Europe in order to study modern aviation and surgery. He was accompanied by another panel member, Dr. Donald Hastings, of the University of Minnesota.

▸ **Glenn L. Martin** (Honorary Fellow, Benefactor, and I.A.S. Past-President), Chairman of the Board, The Glenn L. Martin Company, is the subject of a biography now being written by Ernest K. Gann. Publication is expected early in 1951 by William Sloane and Associates.

▸ **Dr. Parameswar Nilakantan** (A.F.), Deputy Director of Research and Development, Civil Aviation Department, Government of India, New Delhi, India, is the Secretary of The Aeronautical Society of India.

▸ **Capt. J. Laurence Pritchard** (H.F.), Secretary, The Royal Aeronautical Society, was appointed a Commander in the Civil Division, the Most Excellent Order of the British Empire.

▸ **Barbara Pritzkat** (T.M.), Stress Analyst, Northrop Aircraft, Inc., is the former Barbara Ruth Wynn, who was recently married.

▸ **William R. Sears** (F.), Director, Graduate School of Aeronautical Engineering, Cornell University, is in charge of the experiments to be run in the new low-speed wind tunnel at Cornell University on the turbulent boundary layer.

▸ **Sri S. C. Sen** (M.), Civil Aviation Directorate, New Delhi, India, is

Attention Members!

All members of the Institute are invited to submit material concerning their activities for publication in the "News of Members" columns of the *Aeronautical Engineering Review*. Responsibility for new developments, awards or honors received, and appointments to new or additional positions are some of the items that your editors believe are of interest to other I.A.S. Members. A brief letter or postal card giving exact details will be sufficient. Photographs accompanying news items will be welcomed and will be used where practicable.

Items submitted will be considered on the basis of their timeliness and general interest. Correspondence should be addressed to the News Editor, *Aeronautical Engineering Review*, 2 East 64th Street, New York 21, N.Y.

EXECUTIVE VICE-PRESIDENT

Charles H. Colvin, Fellow and I.A.S. Past-President, who was recently elected to the office of Executive Vice-President, G. M. Giannini & Company, Inc., has been placed in charge of all company manufacturing and engineering activities. He was founder of the Pioneer Instrument Company and was formerly associated with Kollsman Instrument Division, Square D Company.

Treasurer of The Aeronautical Society of India.

▸ **Admiral John H. Towers,** U.S.N.R. (M.), Vice-President, Pan American World Airways, Inc., is directing Pan American's air lift to Korea. Prior to the Korean crisis, he was responsible for the on-time arrival of cargo and passengers on the globe-girdling routes.

▸ **Don L. Walter** (T.M.), Manager, Engineering and Manufacturing, Marquardt Aircraft Company, was elected to the Board of Directors of that company.

Members on the Move

This section has been instituted to give information on latest affiliations of I.A.S. members. All members are urged to notify the News Editor of changes as soon as they occur.

Ernesto Watson Saboya de Albuquerque (T.M.), Head, Purchase Department, Codiq S.A., Rua Passa da Patria 1515, São Paulo, S.P., Brazil.

M. G. Beard (M.), Chief Engineer, American Airlines System. Formerly, Director of Flight Engineering, American Airlines.

David Benun (M.), Graduate Student, California Institute of Technology. Formerly, Unit Head, Flutter Engineer, Curtiss-Wright Corporation.

Robert P. Boardman, Jr. (T.M.), Special Assignment, Paint Division, Kaiser-Frazer Corporation. Formerly, Student, Business Administration, University of Michigan.

Walter A. Dommers (M.), President and General Manager, The Dommers Company, Old Saybrook, Conn. Formerly, Director of Field Engineering, Revere Corporation of America.

Morgan B. Eilert, Jr. (T.M.), now with Lockheed Aircraft Corporation.

Dr. Walter Georgii (F.), Professor, Universidad de Cuyo, Mendoza, Argentina, and Director, Aerophysical Institute, Mendoza. Formerly, Scientific Adviser, National Meteorological Service, Ministry of Aeronautics, Buenos Aires.

Malcolm Harned (M.), Project Engineer, Marquardt Aircraft Company. Formerly, Project Engineer, Aerophysics Division, North American Aviation, Inc.

George E. Holback (T.M.), Supervisor, Materials Laboratory, The Glenn L. Martin Company. Formerly, Aeronautical Engineer, The Glenn L. Martin Company.

Garth C. Ladd (T.M.), Aerodynamicist B, Consolidated Vultee Aircraft Corporation. Formerly, Assistant, Aeronautical Department, and Graduate Student, Rensselaer Polytechnic Institute.

Roscoe I. Markey (A.F.), Bell Aircraft Corporation. Formerly, Head, Technical Engineering Division, Fairchild Aircraft Division, Fairchild Engine and Airplane Corporation.

AVIATION CONSULTANT

John R. Griffin, Jr. (M.), recently joined the Technical Staff, du Pont Petroleum Chemicals Division, as Aviation Consultant. He will specialize principally in fuel and lubrication problems in aviation. Holding a Master's Degree in Mechanical Engineering from the University of California, he was formerly associated with The University of Texas, Lockheed Aircraft Corporation, Shell Development Company, Trans World Airlines, Inc., and, most recently, the Sharples Corporation, where he was Chief Engineer of the Research Laboratory.

DEPARTMENTAL HEAD

Dr. Nicholas J. Hoff (A.F.) has been appointed Head, Department of Aeronautical Engineering and Applied Mechanics, Polytechnic Institute of Brooklyn. Dr. Hoff was one of six American scientists who attended the recent General Assembly, International Union of Theoretical and Applied Mechanics, held at Pallanza, Italy. (See page 36 for a report of this Assembly.) He is the first American aeronautical scientist to hold the medal of the Swedish Society of Engineers. Dr. Hoff is also a member of the leading scientific and technical societies both here and abroad.

Harvey McComb, Jr. (T.M.), Aeronautical Research Scientist, Structures Research Division, N.A.C.A., Langley Air Force Base, Va. Formerly, Graduate Teaching Assistant, Purdue University.

Colin H. McIntosh (M.), Vice-President—Operations, All American Airways. Formerly, Director of Operations, All American Airways.

Flight Lieutenant Rodney Noble, #022-173 (T.M.), Officer in Charge, Performance and Handling Section, Aircraft Research and Development Unit, R.A.A.F. Station, Laverton, Australia. Formerly, 20 Milford Street, Randwick, Sydney.

Sam E. Nordyke (M.), Design Engineer, Chance Vought Aircraft Division, United Aircraft Corporation. Formerly, Aeronautical Engineer, U.S.A.F.

Peter H. Redpath (M.), Vice-President—Sales, Canadair, Ltd. Formerly, Executive Vice-President, Overseas Division, Scandinavian Airlines System, Stockholm.

Bazil G. Reed (M.), Superintendent of Maintenance, Fort Worth Plant, Consolidated Vultee Aircraft Corporation. Formerly, Vice-President and Assistant General Manager, Northrop Aircraft, Inc.

Nordae L. Rhodes (T.M.), Mathematician "B," Engineering Department, Structures Group, Control Surfaces and Systems Division, North American Aviation, Inc. Formerly, Student.

NEW POSITION

Bennett H. Horchler (A.M.) recently joined the staff of "Skyways," a J. Fred Henry publication, as Advertising Director. He was at one time Executive Vice-President, Institute of the Aeronautical Sciences.

Don E. Steffe (T.M.), Chief Draftsman, Gametime, Inc. Formerly, Student.

H. C. B. Thomas (A.F.), Head, Mechanical Engineering Department, Royal Aircraft Establishment, South Farnborough, Hants., England. Formerly, Assistant Director, R.D.S., Ministry of Supply, London.

William E. Thompson (T.M.), Instructor, Mechanical Engineering, Illinois Institute of Technology. Formerly, Associate Research Mechanical Engineer, Cornell Aeronautical Laboratory, Inc.

John C. Truman (M.), Development Engineer, Thermal Power Systems Division, General Engineering and Consulting Laboratory, General Electric Company. Formerly, Instructor, Department of Physics, Rensselaer Polytechnic Institute.

Raymond Vachss (T.M.), Design Engineer, Aerojet Engineering Corporation. Formerly, Senior Aerodynamicist, Republic Aviation Corporation.

Harold H. Warden (M.), General Sales Manager, Propeller Division, Curtiss-Wright Corporation. Formerly, Manager, Installations Department, Propeller Division, Curtiss-Wright.

John M. Wild (M.), Chief Engineer, Propulsion Wind Tunnel, Arnold Engineering Development Center, U.S.A.F., Tullahoma, Tenn. On leave of absence as Associate Professor, Aeronautical Engineering, Graduate School of Aeronautical Engineering, Cornell University.

Salvatore X. Xifo (M.), Flight Test Engineer, Northrop Aircraft, Inc. Formerly, Senior Aerodynamicist, The Glenn L. Martin Company.

CHIEF

Herman Pusin (M.), was recently appointed Chief, Structures Department, The Glenn L. Martin Company, after having been Project Engineer, Structures, responsible for the structural design of the Martin P5M-1 Marlin. He has been associated with the Martin Company since 1938, prior to which he was with Porterfield Aircraft and Engineering Corporation for 2 years. From 1941 to 1948, Mr. Pusin taught at the University of Baltimore and at The Johns Hopkins University.

Corporate Member News

• Stock on Market . . . Public offering of 162,010 shares of common stock of **Aeroquip Corporation** was made last July 18 at $4.00 per share by an underwriting group headed by Watling, Lerchen & Company. Of the shares offered, 16,455 were issued by the company and the remainder were sold by certain stockholders. Proceeds are to be used by the company to finance, in part, construction of additional production facilities. Capitalization of the company to be outstanding upon completion of the current financing will consist of 1,699 shares of $5.00 cumulative preferred stock and 750,000 shares of common stock. Net income for 1949, after preferred dividend requirements, amounted to $586,270, or 80 cents per common share.

• New Product . . . **Airborne Accessories Corporation** has produced a new heavy-duty Lineator, Electric Linear Actuator, which has been produced to meet the requirements of stabilizer adjustment on a new swept-wing version of a production A.F. fighter. It has a static capacity in tension or compression of approximately 20,000 lbs. and has a maximum operating load of 7,200 lbs. Normal operating speed is 1 in. per sec. under an opposing load of 2,500 lbs. The complete unit weighs 22 lbs.

• Passenger Agents . . . **American Airlines System** and **Canadian Pacific Railway Company** have signed a passenger sales agency agreement. Under its terms, C.P.R. offices in Canada, Europe, and New Zealand become recognized agents for American Airlines System and American Overseas Airlines.

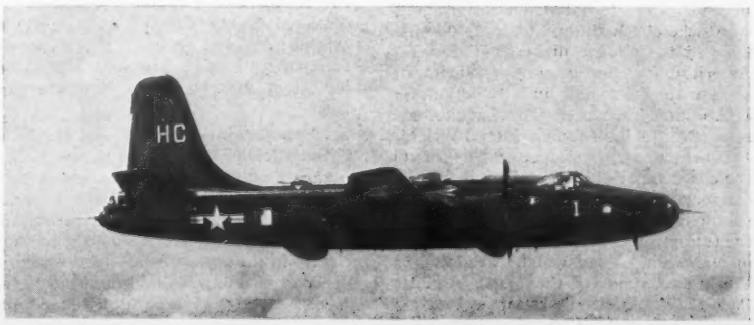
• Air Base Activated . . . **Beech Aircraft Corporation** has exercised its option to rent the Herington Air Base, Kan., from the City of Herington. The base, it is believed, is being reactivated for the purpose of anticipating the need for more space and, particularly, for space that would accommodate large airplanes.

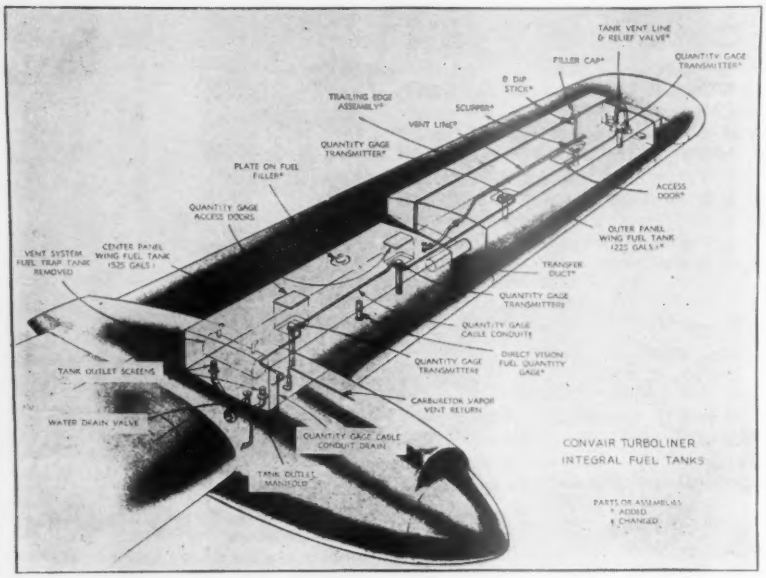
• Helicopters to Belgium . . . Sabena Belgian Airlines took delivery on two new 47-D helicopters, fabricated by **Bell Aircraft Corporation,** for use in the operation of a mail pickup and delivery service out of Brussels. This is believed to be the first time any helicopter has been so used on the continent . . . Bell Aircraft Corporation celebrated its 15th birthday last July 10.

• "Flying Boom" School . . . A school was begun at **Boeing Airplane Company** for a group of U.S.A.F. personnel in an instruction program covering the mechanics and operation of the Boeing-developed "Flying Boom" aerial gasoline refueling equipment . . . The B-29 Superfortress bombers, built by Boeing Airplane Company and

DELIVERY BY MARTIN

The U.S. Navy has taken delivery of the first P4M-1 Mercators, fabricated by The Glenn L. Martin Company. Housed in each of the two nacelles are a Pratt & Whitney R-43 piston engine and an Allison J-33 jet engine. The Mercator, named for the famed geographer, is adaptable for antisubmarine warfare and is equipped with detection devices.





NEW FUEL TANK INSTALLATION INCREASES CAPACITY 50 PER CENT

The new integral fuel tanks in the outer wing panels increase the fuel capacity from 1,000 to 1,500 gal. on the Convair-Liners and Turboliners, fabricated by Consolidated Vultee Aircraft Corporation. A structural weight increase of only 339 lbs. was found necessary in designing the extra fuel tanks.

delivered to the R.A.F., have been given the British designation "Washington."

• Profit Sharing . . . . **The Cleveland Pneumatic Tool Company** has announced a new profit-sharing plan, recently approved by the U.S. Bureau of Internal Revenue and set up for the benefit of shop and office employees. All workers who are entitled to overtime pay are eligible. Each employee will receive a third of his total year's share in cash, with the remainder being held in a retirement trust fund. Under the plan it is said that it is possible for the employees' share to reach 50 per cent of profits . . . The Cleveland Pneumatic Tool Company has acquired the license and manufacturing rights of the Dowty Liquid Spring Shock Absorber, England, for aircraft undercarriages.

• Conversion . . . All B-36A bombers, built by **Consolidated Vultee Aircraft Corporation,** have been returned to the Convair plant for conversion into an RB-36A reconnaissance airplane. The first converted bomber was completed last July.

• Flight Simulators . . . The Propeller Division, **Curtiss-Wright Corporation,** has negotiated an international licensing agreement whereby Redifon, Ltd., of London, is licensed to produce flight simulators for American- and European-designed aircraft similar to those now in production for U.S. military services. These simulators, which will be built under Curtiss-Wright-Dehmel patents, reproduce on the ground the characteristics of aircraft in flight and can markedly reduce the time lag between the delivery of new tactical aircraft and the training of crews needed to place them in operation. They will be available to European nations of the North Atlantic Pact and other friendly countries.

• Modernization Order . . . **Douglas Aircraft Company, Inc.,** has received an order from the Navy's Bureau of Aeronautics for the modernization of 100 R4D twin-engined transports into military versions of the new Douglas Super DC-3. The Super R4D's will be powered by Wright 1820-C9HE engines, which will drive Hamilton Standard high-activity propellers.

• Contract . . . An Air Force contract has been signed for a substantial additional number of C-119 Packets, the twin-engined troop and cargo transport planes manufactured by **Fairchild Aircraft Division,** Fairchild Engine and Airplane Corporation.

• Demagnetizing Coil . . . An improved design of demagnetizing coil has been developed by General Engineering and Consulting Laboratory, **General Electric Company.** The instrument is said to be effective in demagnetizing materials and stabilizing magnetic flux. It may be used on any unshielded magnetically soft material, including forms of iron and steel.

• Safety Award . . . **The B. F. Goodrich Company** has been granted the Distinguished Service to Safety Award of the National Safety Council as a result of establishing, last year, the best annual safety record in its history. The award has been granted on a company-wide basis.

• Turbo-Hydromatic . . . **Hamilton Standard Division,** United Aircraft Corporation, announced the successful test-flying of its first propeller designed for use with gas-turbine engines. An electronic "brain" gives quick response to any change in the speed of the engine and propeller or to the pilot's adjustment of the speed setting. It is designated the "Turbo-Hydromatic" . . . The first of an order for air-conditioning units for the North American F-95A jet fighter was to be delivered this summer by Hamilton Standard. The unit, which is scheduled to go into full-scale production later this year, weighs 20 lbs. It delivers a 120-m.p.h. hurricane of air to the fighter's cockpit to change its 60 cu.ft. of air every 15 sec., thus maintaining a constant temperature.

• Contracts . . . **Lear Incorporated** has announced the receipt of Air Force contracts in excess of $3,300,000 for Lear automatic pilots and gyro instruments. Previously, the Department of Defense disclosed the awarding of a contract to Lear for more than $400,000 covering Automatic Approach Couplers . . . Lear has introduced a rotary actuator that weighs less than 1 lb. and yet develops a maximum peak output of 110 in.lbs. with a normal rated peak load of 60 in.lbs. Designated as Model 167A, the actuator produces a nonlinear torque output that approximates typical aircraft duct damper and fuel valve load curves . . . Lear has acquired the balance of 9,600 sq.ft. of space in the main building that it purchased last year. This space, formerly under lease to another firm, is to be used for the increased production of autopilots, gyros, electromechanical actuators, automatic controls, servomechanisms, aircraft radios, and other aircraft accessories.

• Orders . . . Two substantial orders have been placed with **The Glenn L. Martin Company** by the U.S. Navy for P5M-1 Marlin antisubmarine seaplanes. The Marlin, the first postwar twin-engined flying boat developed for the Navy, will be powered by two Wright 3350-30 compounded engines rated at 3,250 hp. Propellers are four-bladed, square-tipped Hamilton Standard . . . The Martin 2-0-2A twin-engined air liner has been certified by the C.A.A. for a gross take-off weight of 43,000 lbs. The original 2-0-2 airplane was certified at 39,900 lbs. for take-off.

FLYING TEST BED

After completing ground tests successfully, the Orenda turbojets, built by A. V. Roe Canada Limited, were subjected to actual flight conditions for further testing when taken aloft in a specially built Lancaster. The Orenda, a prototype of which is seen in the picture below in the outboard-engine position, was built to power the Avro CF-100, an all-weather, long-range, day-night fighter.

• Booklet . . . The Aeronautical Division, **Minneapolis-Honeywell Regulator Company,** has published a booklet on the *Dynamic Stabilizing System.*

• Initial Tests . . . The first production version of the U.S.A.F.'s Scorpion F-89, built by **Northrop Aircraft, Inc.,** has successfully completed its initial flight.

• Airlift . . . Four days after the Korean fighting broke out, **Pan American World Airways, Inc.,** had put into operation a 7,000-mile logistic air lift to Korea. A special air fleet, composed of 27 DC-4's and Stratocruiser Clippers, was culled from its own equipment and from seven other international and domestic air lines as subcontractors.

• Survey . . . A recent survey shows that the subcontractors and suppliers of **Pratt & Whitney Aircraft Division,** United Aircraft Corporation, have reached a total of 4,604 concerns.

• Accelerated Service Test . . . Last July, the F-84E Thunderjet, manufactured by **Republic Aviation Corporation,** was back in the air after having successfully completed the fastest accelerated service-test program on record. The airplanes were grounded early in the Korean fighting because of faulty oil-pump equipment on the Allison J-35 engine. Five F-84's in which revised oil-pump equipment had been installed flew for a total of 105 hours and 45 min. within one 24-hour day. A sixth was flown for 23 hours and 5 min. out of a single 24-hour period . . . The Republic YF-96 has been turned over to the Flight Test Section, Air Materiel Command, for Phase Two performance capability tests, following completion of its initial test program.

• Subcontract . . . The largest single order since World War II was recently received by **Ryan Aeronautical Company,** bringing contracts received in the 30 days preceding August 7 to over $10,000,000. A new subcontract with Boeing Airplane Company calls for an increased production at Ryan of the aft fuselage sections for the Air Force's C-97 Stratocruiser military transports. Ryan also holds Air Force and Navy prime contracts for jet-propelled target planes, guided-missile research, new applications of jet propulsion and exhaust systems, and other such work.

• Gasoline-Truck Refueling . . . A method of refueling aviation gasoline trucks from the bottom, thus ensuring safer, easier, and more economical loading operations, has been adopted by **Shell Oil Company, Inc.,** at Washington Airport. A coupling and valve arrangement, linking the bottom of the truck with the free end of the delivery hose, prevents leakage and permits excellent control of the flow of gasoline. High-octane gasoline is pumped in at the rate of 200 gal. per min.

• Zero Readers . . . Production orders for the Zero Reader flight instruments have been received by **Sperry Gyroscope Company,** The Sperry Corporation, to equip the new Northrop F-89 . . . Boeing Airplane Company has purchased a sizable quantity of Model A-12D Gyropilots from Sperry in order to provide automatic flight control for B-47B jet bombers.

• New Sales Area . . . **Trans World Airlines, Inc.,** has opened a new district sales area for the Pacific Northwest with headquarters at 527 Skinner Building, Seattle . . T.W.A. announces the establishment of a district sales office at the Alexander Young Hotel in Honolulu . . . T.W.A. has taken delivery on the first of its new fleet of 42 twin-engined Martin aircraft . . . Individual awards for excellence of proven sales ideas and techniques are being given in four categories—cargo, agency, passengers, or mail and express—to traffic representatives of T.W.A. through a new sales-stimulating campaign known as "Salesman of the Month" award. A framed certificate and a U.S. Government Savings Bond is presented to each winner each month.

• Ionization Gage . . . **Westinghouse Electric Corporation** has developed a new ionization vacuum gage that can be used to measure pressures as low as 5 by 10^{-10} mm. Hg. This gage can be operated on standard power supplies and is furnished with special tabulation for direct reading to various types of glass systems.

• Re-Engining . . . A $4,000,000 order for Cyclone 9 engines has been placed with the **Wright Aeronautical Corporation.** The engines covered by this order will be used for re-engining a part of the Navy's present fleet of R4D transport planes.

FOR CAA SAFETY
AT OXYGEN ALTITUDES

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OXYGEN MASKS

These exceptionally efficient and comfortable new masks have been developed by the makers of the first true aviation oxygen masks in co-operation with the nation's top aero-medical experts. Unique valve and rebreathing system gives greater oxygen economy at all altitudes. Amazingly lightweight, streamlined design gives freedom of vision and movement, conforms to facial contours for a close yet surprisingly comfortable fit. Specially formulated Arctic latex stays flexible even at 65° below zero.

A-14 (Shown above) — For greatest oxygen economy with demand-type systems. Effective with or without helmet.

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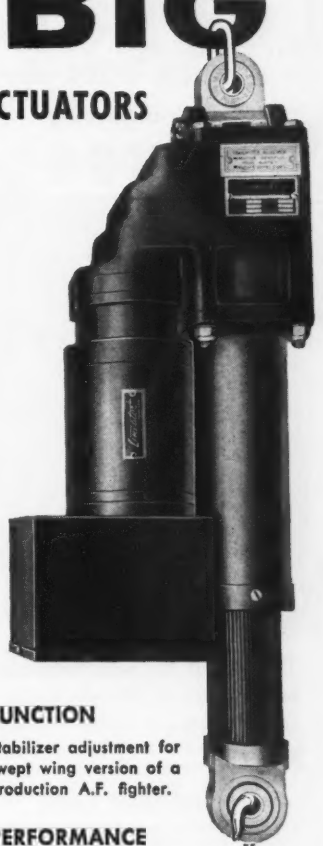

FUNCTION
Stabilizer adjustment for swept wing version of a production A.F. fighter.

PERFORMANCE
Static Load Rating: 20,000 lbs.
Maximum Operating Load: 7,200 lbs.
Operating Speed: 1 inch per sec.
Weight: 22 lbs. (Including Radio Noise Filter).

FEATURES
(1) Overload Clutch with *external* adjustment.
(2) Non-jamming Positive Overtravel Stops.
(3) Position Transmitter & Radio Noise Filter built-in.
(4) 1.65 H.P., 26 Volt D.C. Motor with Magnetic Brake & Clutch.

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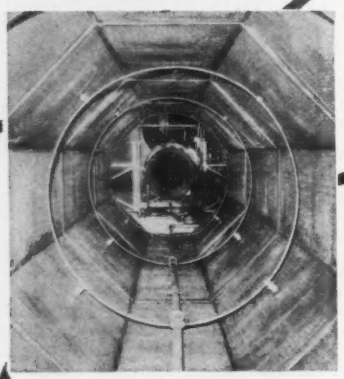

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I.A.S. Sections

Baltimore Section

Welcome W. Bender, *Secretary*

Robert O. Bonnell, Member of the Baltimore City Airport Board, spoke on "Building an International Airport" at the year-end meeting of July 12 at the Stafford Hotel.

▶ **Friendship Airport**—Mr. Bonnell, who is also a Vice-President and a Member of the Executive Committee, Fidelity Trust Company, presented a résumé of the development sequence in the construction of Friendship International Airport, which serves the Baltimore - Washington - Annapolis area. The airport was originally considered in 1943 and was dedicated by President Truman on June 24, 1950. During the intervening period, the entire planning for the site was carried out with a view toward: freedom from obstructions, approach characteristics, topography, meteorological conditions, land costs, revenue possibilities, and future expansion. In addition, many legislative problems had to be solved such as adequate zoning to prevent obstructions, taking care of displaced families, and the movement of 14 cemeteries. The total cost of the 3,200-acre Friendship International Airport amounted to approximately $15,000,000 of which $3,000,000 represented Federal funds.

Vice-Chairman Ralph Draut welcomed the following new officers for the ensuing year: Chairman, George N. Mangurian; Vice-Chairman, Capt. George J. Higgins, U.S.N.R.; Secretary, H. Erich Nietsch; Treasurer, Herman Pusin.

Dayton Section

Robert W. Hoeflein, *Secretary*

The following officers were elected for the 1950–1951 season: Chairman, Ezra Kotcher; Vice-Chairman, Major F. J. Sweet; Treasurer, Miss E. M. Kriegsmann; Secretary, Major W. A. Barden.

Los Angeles Section

H. A. Storms, *Secretary*

On June 10, at 7:30 p.m., approximately 130 members and guests were present for a "social mixer" at the Institute's Western Headquarters Building. The evening's activities were initiated by H. Luskin, Master of Ceremonies, with the presentation of four motion pictures, which were as follows: *Highway to Hawaii*, a travelog of Hawaii presented through the courtesy of United Air Lines, Inc.; *Fury in the Pacific*, a Navy combat picture describing a typical beach landing during World War II; *Airplane Oddities in the News*, comic versions of the airplane as shown in a U.S.A.F. film; and *I.A.S. Visit Aboard the "Valley Forge,"* a 2-min. picture describing activities aboard this aircraft carrier during the I.A.S. Field Trip.

At the conclusion of these movies, those attending enjoyed dancing and games while refreshments were being served. The evening's entertainment was termed a huge success by everyone attending, and a vote of thanks is due E. P. Hartman and his committee for their efforts.

Washington Section

Bernard Maggin, *Secretary*

[EDITOR'S NOTE: Because of reorganization in the Editorial Staff, the following report was overlooked and unfortunately was not published in an earlier issue.]

The March meeting of the Washington Section, "Air Force Night," was preceded by a dinner for the speakers of the evening, Major Gen. F. O. Carroll and Col. G. W. Goddard, of the U.S.A.F. The dinner was attended by 82 and the meeting by 180 Institute members and their guests.

The meeting was opened by W. H. Miller, Vice-Chairman, who introduced Major General Carroll, Chief, Air Engineering Development Division, Headquarters, U.S.A.F. General Carroll delivered the first talk on the "Air Engineering Development Center" and then introduced Colonel Goddard, Chief, Photographic Laboratory, A.M.C., Wright-Patterson Air Force Base, Dayton, Ohio, who spoke on "Air Force Research and Development in the Field of Aerial Photography."

▶ **Air Engineering Development**—In outlining the Air Force's plans for the projected Air Engineering Development Center, for which some funds have been appropriated, General Carroll pointed out that the Center would have two prime objectives. The first objective is to provide facilities and personnel capable of evaluating equipment for conformance with specifications. The second objective is to provide facilities and personnel with which industry can carry out necessary development work in the propulsion and aerodynamic fields.

In 1946, after a study of about 25 areas throughout the country, a site near Tullahoma, Tenn., was selected

(*Continued on page 88*)

Meet Your Section Chairmen

William O. Meckley

Boston Section

William O. Meckley, Division Engineer, Aircraft Gas Turbine Division, General Electric Company, originally from Philadelphia, was graduated in 1940 from the University of Michigan with a B.S. degree in Mechanical Engineering. An analysis and evaluation of the industrial situation at that time brought about the decision to foster a lifelong interest in aviation by entering the aeronautical field in which there were ample opportunities for a sedulous young man.

▸ **Citation**—At the Aircraft Gas Turbine Division, Mr. Meckley has been associated with the cooperative development with Pratt & Whitney Aircraft Division, United Aircraft Corporation, of new piston and turbosupercharger-type power plants. In recognition of his work on this project, he received General Electric's highest citation, the Charles A. Coffin Award for 1949. He was also on a special N.A.C.A. Committee for the development of flight-test method and procedure.

▸ **Author**—Mr. Meckley is the author of a paper entitled "Jet Nozzles for Aircraft Gas Turbines" that appears on page 33 of this issue. In addition, he has written other papers on Exhaust Ejector System and Compounding Engines that have been published in various aeronautical journals. He spoke on the subject of the "Flying Test Bed" at the 1945 A.S.M.E. Annual Meeting.

Golf, baseball, and swimming are Mr. Meckley's forms of relaxation. He is married and is the father of two boys, aged $5^1/_2$ and 3.

Robert William Kluge

Buffalo Section

Robert William Kluge, Assistant Head, Aero-Mechanics Department, Cornell Aeronautical Laboratory, Inc., has maintained an interest in aviation ever since Charles Lindbergh's epochal transatlantic flight to Paris in 1927, when 9-year old Master Kluge became, as he terms it, "an aero-nut." When the time came for him to choose his profession he "decided that the combination of usefulness, beauty, and glamor" made aviation an unbeatable career.

Born 32 years ago in Cleveland, he was graduated from Case Institute of Technology with a B.S. degree in Mechanical Engineering. His first employment, back in 1938, was as a Draftsman with Lockheed Aircraft Corporation. This was followed by a period with Consolidated Vultee Aircraft Corporation as a Stress Analyst. In 1939, he joined Bell Aircraft Corporation as Assistant Chief Structural Engineer. He remained at Bell until 1946, when he became associated with Cornell Aeronautical Laboratory, Inc. His present duties there include various fields of guided-missile research and development, helicopter research, aircraft equipment, and experimental flutter research. He is credited with certain classified inventions in the fields of power plants and small arms.

▸ **Scientific Consultant**—A high spot in Mr. Kluge's career was his appointment as Scientific Consultant to the Technical Industrial Intelligence Commission. From May to September, 1945, he conducted a survey of the German Aircraft Industry with his time being divided between trips to Germany and documental study in London.

When asked about his hobbies and other activities, Mr. Kluge replied that his hobbies included baseball, swimming, flying, and sleeping and that his other activities consisted of night school at the University of Buffalo. He is an airplane pilot and has logged over 200 hours on a Waco F-2, a Fairchild 24, Stinson Voyager, a Monocoupe he once owned, a Schweizer Sailplane of which he is part owner, etc.

Mr. Kluge is married and is the father of a boy, age $5^1/_2$, and a girl, age $3^1/_2$.

How to Harness 3250 Horsepower for Smooth Performance

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The MR-43 Dynafocal has an exceptionally low natural frequency which enables it to isolate as much as 95% of engine vibration. The new type flexing element has greater oil resistance . . . is easier to clean and inspect . . . and is conservatively stressed. These and other improvements extend service life and improve performance.

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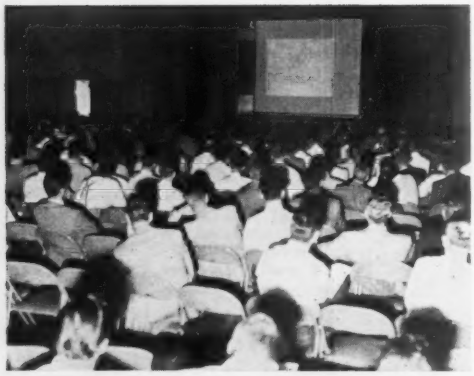
North



Editorial

"We Look Before and After"—

As we finish our fiscal year on September 30, a quick glance at our "howgozit" chart tells us that once again the Institute has come through a 12-month period "in the black." The exact figure must await the final analysis of our Controller and the scrutiny of our auditors, but the preliminary calculations show that we have been living within our income—with a little to spare. This is encouraging, because, as yet, neither the industry nor the Institute has received much fiscal benefit from the increased activity in the Armed Services resulting from current uncertainties in world affairs. Further, there have been no cutbacks in Institute services. We have been rolling steadily ahead on all fronts.

But this year we are concerned primarily with problems of the future. We cannot afford to spend too much time on past accomplishments. With the world teetering on the brink of a Third World War we must re-examine every phase of I.A.S. activity not only to ensure that we continue to operate without loss but

West

South

particularly to guarantee that the Institute will serve the needs of its members in the difficult years that lie ahead.

It is not enough that an organization such as ours spends its effort simply in perpetuating itself through times of crisis. The real objective is to use the facilities we possess to further the interests of our membership and of the National Defense.

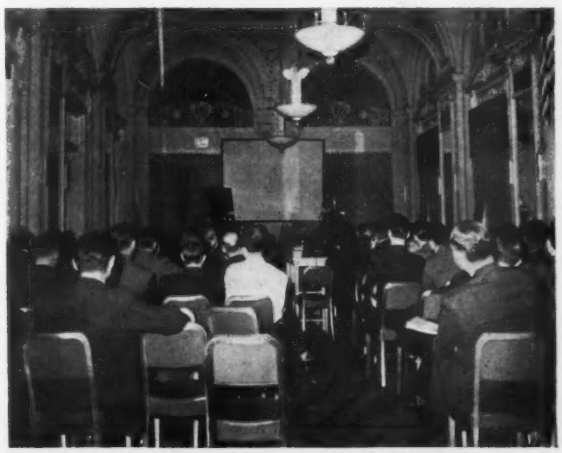
The Institute of the Aeronautical Sciences is an indispensable part of the fabric of National Defense. Our members, corporate and individual, form the warp and the woof of the aircraft industry. By serving their needs we strengthen the whole and thus make our contribution to the general welfare.

During the past few weeks, the I.A.S. Council and staff have been preparing an "emergency" plan for the conduct of the Institute in the event that the present crisis leads to war. Many matters have been considered, down to the protection of our records and our personnel in event of direct attack on our cities. The details are not of significant interest here. What is important, however, is the agreement of all concerned that *the basic policies and objectives of the Institute shall remain unchanged.*

Our job has always been to provide our membership with the maximum of technical and scientific data to assist them in providing our military services, our air lines, and our private pilots with the most advanced aircraft available. That obligation does not change. Rather, it is intensified in time of crisis. At the same time, security and other restrictions make our problems more difficult. But there are ways and means of overcoming such difficulties, and we are pledging ourselves to exert all possible means at our disposal to continue the work of your Institute to provide the maximum benefit to all, no matter what happens.

Discussions have already been undertaken with the Armed Services, the Research & Development Board, the N.A.C.A., the A.I.A., and other agencies regarding cooperative action with the I.A.S. in any emergency. We would welcome suggestions from any member on this subject. We must all collaborate and cooperate to the highest possible degree in advancing the arts and sciences of aeronautics for the future security of our country and of the world.

S. P. J.



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Operational Feasibility of Aircraft Through Thunderstorms

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Introduction

The Thunderstorm Project originated in 1945 when Congress, spurred by a grim record of civil and military aircraft accidents, approved an appropriation to be used in the study of thunderstorms. The project was organized with the U.S. Air Force, Navy, Weather Bureau, and the National Advisory Committee of Aeronautics as participating agencies. Other agencies, C.A.A., C.A.B., and universities cooperated.

A Thunderstorm Advisory Committee, comprised of outstanding civilian and military scientists, outlined the general plan of investigation. The program was divided into two phases: the first to be conducted in Florida where subtropical thunderstorms are encountered; the second phase to be carried on from a more northern base where storms of the frontal and prefrontal type could be found.

Various means of gathering data were to be utilized. Aircraft, properly instrumented, would be flown through the storms, and a network of ground weather stations would observe and record surface data and upper-air soundings. Ground radar, in addition to controlling the aircraft, would be used for the study of cloud echoes produced by the thunderstorms.

The aircraft chosen for the project was the Northrop P-61 Black Widow night fighter. This airplane was selected because of its availability, proper stress specifications (N.A.C.A. specified an ultimate load factor above 7*g*), high service ceiling, and complement of radar equipment, which included the SCR-718 and SCR-720.

A surface network was planned consisting of 55 automatic recording weather stations and six Rawinsonde (SCR-658) and four Rawin (SCR-584) stations. Operational procedure called for aircraft to fly the storms as they passed over the surface network. In this manner, data from air and ground could be closely correlated.

Phase One was carried out at Pinecastle A.A.F., Orlando, Fla. The first mission was flown on June 27, 1946, and flights were continued through September 18, 1946. A total of 38 missions, consisting of 554 traverses through thunderstorms, was made.

In October, 1946, the project was moved from Orlando to the All-Weather Flying Center at Wilmington, Ohio, for Phase Two work. This midwestern location was selected because it would provide frontal and prefrontal thunderstorms as compared to the subtropical types found in Florida. Aside from speculation, little was known as to the comparative intensity of the two types. The general consensus was that frontal storms were more violent.

Relatively little thunderstorm activity is experienced during the winter months in the Ohio area, and this time was utilized in preparing for the following summer's operation. All surface equipment of the weather network was recalibrated and installed. The aircraft were sent to Patterson Field for modification and inspection. Particular effort was directed toward determining whether the aircraft had suffered any structural damage during the Florida flights. No evidence of major damage was found. However, skin surface cracks due to metal fatigue were found in several instances.

By May 13, 1947, preparations had been completed, and the project went on operational status. A general description of the various units involved and how they functioned follows.

Ground Network

The ground network was composed of 55 automatic recording weather stations placed 2 miles apart and covering a rectangular area of approximately 160 sq. miles. This area began some 5 miles south of Clinton County and continued southward approximately 20 miles. Each station was equipped with modified AN/GQM-1 wind instruments, hygrothermograph, microbarograph, rain gages, and electronic dew-point indicator. Sunshine recorders were also installed at two stations. Seven Rawinsonde (SCR-658) and five Rawin (SCR-584) stations for gathering upper-air data were set up. Four of these stations were located within the network and the remainder at various points surrounding it. The automatic stations were in operation 24 hours daily, and records were collected daily. Special balloon releases were made from the Rawinsonde and Rawin stations during thunderstorm activity, in addition to regularly scheduled releases.

Ground Radar

Two radar setups, the AN/CPS-6 and the AN/CPN-18, were utilized for controlling the aircraft and gathering radar history of the thunderstorms. The AN/CPN-18 was located on the air base and had a range of approximately 40 miles. Despite the limited range of this set, it was necessary to use it during the early states of the project while work was being completed on the V-Beam (AN/CPS-6). This set was erected at Jamestown, Ohio, some 15 miles north of Clinton County AFB and went into operation on July 11. Its greater

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range (maximum 200 miles) made it much more desirable than the CPN-18.

Control of the aircraft was effected by the use of the APN-19 Radar (Rosebud) transpondor beacon in the aircraft. This transpondor produces a coded signal identifying the plane on the PPI scopes. When heavy precipitation blocked out the normal video, the signal could be read by shifting the radar to beacon video. Additional scopes, aside from those normally used by the controller, were set up, and photographs were taken at 10-sec. intervals. This provided permanent records for later reconstruction of changing echoes or "radar history" of the storm. The photographs also indicated the position of all aircraft with respect to the cloud echo at any particular time.

The AN/TPS-10 height-finding radar was used to scan the storm area during operational missions. Photographs of this scope were made approximately every 4° of azimuth or once every 2 sec. This equipment was the most reliable means of measuring the vertical extent of a storm.

Aircraft Instrumentation

All P-61 aircraft used on the project were equipped with the following complement or instruments and equipment: (1) Accelerometer (N.A.C.A.); (2) Airspeed-altitude Recorder (N.A.C.A.); (3) Control Position Recorder (N.A.C.A.); (4) Thermistor or Recording Thermometer (Weather Bureau); (5) SCR-720 Airborne Radar Set; (6) SCR-718 Radio Altimeter; (7) Electro-static Field Indicator; (8) Photopanel; (9) Wire Recorder (AN/ANQ-1A); (10) Synchronizer; and (11) APN-19 (Rosebud) Transpondor Beacon.

The first four instruments listed above were self-recording and required only that they be turned off and on so as to record at the desired time. Items 5, 6, 7, and 8 were photographed by 35-mm. motion-picture cameras. The photopanel contained a duplicate set of flight instruments. It was found impractical to photograph the pilot's instrument panel during flight because of varying light conditions, presence of snow and rain in the cockpit, etc. A duplicate pilot's panel was installed in the radar compartment and photographed once every 4 sec. The wire recorder was used to record crew comments during a mission. The function of the synchronizer was to pick up an audio signal transmitted from the ground over a V.H.F. and convert it into a blinking light located on the photopanel. This signal was transmitted at 5-min. intervals and provided the means for synchronizing all ground and air operations.

One AT-6 aircraft was used for the study of cumulus clouds prior to their growth into thunderstorms. This plane contained the same instruments and equipment as the P-61's with the exception of the radar units.

Flight Operations

Five aircraft and crews were alerted daily for a 12-hour period during which the weather forecasters felt thunderstorm activity was most likely. The Weather Bureau radar observer and AN/CPS-6 controllers alerted the aircraft for take-off when it was determined (through previous weather soundings, reports from the ground network, radar echoes, and reconnaissance aircraft) that suitable thunderstorm activity was developing. Approximately 30 min. was required for the aircraft to reach their assigned altitudes and get into position to make penetrations. Because of this time factor, every effort was made to take off before any thunderstorms were actually visible on the PPI scopes. This made possible penetrations in the storm through all its stages—i.e., building, peak, and dissipating.

After take-off, each aircraft checked in with the radar controller and remained under his control until the mission was completed. The controller vectored the aircraft on such headings as to give them time to reach their assigned altitudes (6,000, 10,000 15,000, 20,000, and 25,000 ft.) and to obtain separations in trail of approximately 2 min. A suitable storm was then selected by the controller from echoes appearing on his scopes and from pilot information. Actual traverses were begun with the ground controller giving the aircraft vectors that would take them through the heart of the storm as indicated by the radar echo.

Since the return on the PPI scope indicated only the precipitation area of a thunderstorm, it was sometimes necessary for the pilot to select the exact heading that would take him into the center of the cloud structure. This was particularly true when the storm was in the building stage and contained only a relatively small amount of rain. The radar observer turned all special instruments and cameras "ON" approximately 3 or 4 miles before actual entry into the storm and "OFF" again when the aircraft broke clear. In many instances the thunderstorm would be so surrounded by the stratus and smaller cumulus clouds that the aircraft would be on instruments throughout the entire mission. In situations of this kind, the aircraft instruments and cameras were turned off and on at the discretion of the ground controller.

Each plane would average five to ten traverses during a mission. During each traverse the weather and radar observers kept a log noting time of cloud entry and exit, location and intensity of areas of precipitation and turbulence, lightning flashes, formation of ice on the aircraft, etc. Pilot comments were picked up on the wire recorder.

Immediately after the mission was completed and the aircraft had landed, the crews were interrogated. The pilot and radar observer of each crew were interrogated separately from their weather observer. This was done so that completely unbiased impressions could be obtained. The addition of a weather observer to the regular two-man crew used during Phase One greatly improved the value of these postflight interrogations. Not only could the observations of one be used to corroborate the other, but the weather observer was always free to make notes at times when pilot and radar observer were occupied with more pressing duties.

Summary of Flights

During the period of May 13 to September 26, the P-61's flew a total of 38 thunderstorm missions consisting of 812 traverses. Since sufficient personnel was not available to permit continuous 24-hour operation, flights were alerted to the 12-hour period of most likely thunderstorm activity. Generally, flights took place between 1,100 and 1,800 hours. Two missions were flown between midnight and 0200.

The majority of the storms encountered were traversed without undue difficulty. However, a sufficient number gave positive proof that a thunderstorm can never be regarded lightly. The intensity of turbulence within a particular storm appears to be a function of its stage of development, and to date no method of determining that stage prior to entry has been devised. Extreme conditions of turbulence may not always be encountered when flying through thunderstorms; nevertheless, at some time and place within a storm, conditions may be severe. Hence, the practical approach is to prepare for the condition.

In addition to the 38 thunderstorm missions, 13 special flights were made. Seven of these were made for the purpose of investigating weather connected with a radar phenomenon called "bright-line" and the "seeding" of clouds with dry ice. The remaining six flights were cumulus-cloud studies made in the AT-6 type aircraft. The object was to obtain data on the cloud from the time it first appeared in the sky until it developed into thunderstorm stage.

Preliminary Findings

Since A.A.F. airplanes are of all types, sizes, and characteristics and fly in all sorts of weather at different altitudes over many types of terrain, the major problem is to correlate all available information that can be obtained on turbulence and intensity. The method followed has been to fly the aircraft into the storms and deduce the gust characteristics from both the real and apparent reactions of the planes.

The major portion of the data on thunderstorm gust structures has been obtained through photographic records of acceleration and air speed as a function of time. The gradient distance is taken as the time from zero to peak acceleration increment multiplied by the true air speed. The spacing is obtained from the time between accelerations, peaks, and air speed. The distribution of gust velocity along the airplane span has been determined by recording the local wing pressures at various stations along the span and the air speed.

The gust spacing the sequences of gusts encountered has been determined by measuring the time between acceleration peaks on accelerometer records. The determination of intensity of horizontal gusts has been obtained from air-speed records on the assumption that absolute velocity of the airplane tends to remain a constant in spite of the rapid changes in wind speed which the airplane experiences.

Consideration of the instrumental and reading errors in evaluating the data, together with a knowledge of the problems involved in the reactions of an airplane, indicates that the possible errors can be as follows: (1) gust velocity based on accelerations—plus or minus 10 per cent; (2) gust velocity from pressure instruments—plus or minus 4 ft. per sec.; (3) lateral gust gradient distance—plus or minus 20 per cent.

Of the 1,300 penetrations made by Air Force pilots and some 300 previous ones by N.A.C.A., without a major accident or fatality, the severest recorded sharp-edge gust measured 43 ft. per sec. This occurred on the seventh penetration of the same Ohio Storm at the same 15,000-ft. altitude. On every run prior to that the pilot reported turbulence from "light to moderate."

In his postflight interrogation the pilot said the "jolt was so severe that I thought I had collided with another plane. I was unable to keep my hands on the controls, they banged around so much."

Film records from the N.A.C.A. accelerometer show that the airplane traversed $2^1/_2$ min. of smooth air just prior to entering the storm cloud (the maximum effective gust velocity encountered was -3 ft. per sec.). Five seconds after entering the storm cloud the airplane experienced a gust sequence imposing accelerations on the airplane $+1.49$, -1.16, $+1.99$, and $-1.45g$. The duration of this sequence was 5 sec. and corresponded to effective gust velocities of $+35$, -24, $+43$, and -29 ft. per sec., respectively. It is thought that the element of surprise and the sequence of four large alternately positive and negative gusts were the main factors contributing to the temporary loss of control of the airplane. It is interesting to note that effective gust velocities of 30 ft. per sec. were encountered during previous runs without comment from the pilot. No major structural damage was incurred by the aircraft. Skin cracks up to 2 in. in length were found on the horizontal stabilizer.

Inspection of the air-speed-altitude record shows that the above gust sequence occurred in the shear layer of a large draft that carried the airplane from an altitude of 14,800 to 20,000 ft. in 70 sec. The maximum draft velocity from this region was 103 ft. per sec. The average draft velocity was 75 ft. per sec.

The pilots used on the project were all volunteers and former A.A.F. instructors in instrument flying. Their total experience level ranged from 1,100 to 6,000 hours per man. All were proficient in every phase of instrument flying. Although only two of the pilots had green instrument cards, all were able to pass the standard A.A.F. green-card check. At the conclusion of the project, the pilots expressed a unanimous opinion that no one should fly thunderstorms unless he could pass a green-card check.

All pilots were trained to use as little aerodynamic control as possible. Corrective action was taken only after major or dangerous displacements of the airplane appeared to be taking place.

It was found that the pilot is a significant factor in severe turbulence as to the total loads on the airplane.

the variation shown on the basis of N.A.C.A. statistics being of the order of 20 per cent from pilot to pilot in the same rough air. In continuous rough air this amplification of load due to control movement can be appreciable and might mean the difference between getting through or falling out of control; hence, the insistence on attitude flying with as little elevator control action as possible. This kept from setting up a pitch oscillation that could ultimately lead to excessive control movement and possible structural failure.

What Is a Thunderstorm?

Every day some 44,000 thunderstorms spatter their violent contents over the world's surface. At least 1,800 of these churn the earth's atmosphere every minute and discharge 100 flashes of lightning each time the clock's second hand moves. The Carnegie Institute of Terrestrial Magnetism finds this lightning alone represents a continuous transfer of energy equaling 268,000,000 hp., about 2 hp. for every man, woman, and child in the United States and its possessions.

The ordinary cumulus cloud that dots the midsummer's sky from coast to coast gives the thunderstorm its birth. As air becomes unstable, the atmosphere attempts to regain equilibrium and re-establish a stable condition. The greater the instability, the more violent overturning is required to return the atmosphere to equilibrium and larger and more numerous cumuli appear in the sky. The thunderstorm is the visible "turning-over" in the atmosphere's attempt to regain stability.

A thunderstorm is composed of several cells that vary in diameter from 1 to 5 miles, depending upon the stage of development. The life cycle runs between 2 and 3 hours. As old cells die, new ones build up. A full-grown cell has been measured as high as 67,000 ft., making it impossible for present-day tactical aircraft to fly over the top.

These cells, usually in the form of horizontal ellipses and spanning up like chimneys, are the areas of greatest turbulence, with a definite gust minimum between cells. The in-between space, up to $1^1/_2$ miles in width, is large enough to provide any size aircraft a comparatively smooth ride. If it can be accurately located, it is believed possible to fly the severest storm with ease, for this area is often devoid of gusts whose vertical velocities measure less than 2 ft. per sec.

However, there is no practical instrument at the present time (several are in the experimental stage) which will enable a pilot to follow its indications and find the "soft" spot through any thunderstorm.

The life cycle of a cell is divided into three parts: (1) development or cumulus stage; (2) peak or rain stage; (3) dissipation or anvil stage.

In the development stage the updraft prevails throughout the entire cell, varying from a few to 1,000 ft. in large well-developed cells. With height, the vertical currents increase. The tops of the cloud at this stage are about 15,000 ft.

The presence of large amounts of water and ice particles, carried upwards and liberated by the sharp updrafts of the building cell, lead to drop coalescense. These conditions persist until the condensation and drop coagulation within the cell become so heavy that the updraft is no longer able to carry the increasing amount of water.

To the pilot flying through, this stage is characterized by a cloud so dense with misty rain that it is difficult to see the wingtips. As this mist coagulates into heavy drops, water begins to fall through the ascending air currents and the downdraft becomes well established. At this point the cell passes into its peak or rain stage.

About the time that rain first reaches the surface, a complete change takes place within the cell structure. A strong downdraft develops in regions where updrafts previously existed. With height, the downdraft decreases both in speed and in volume.

The cell contains a sharp updraft and downdraft adjacent in the lower levels. This downdraft spreads across the lower regions of the cell until in the final stage only down motion remains. In the upper third of the cell, above 30,000 ft., the downdraft ceases entirely and an updraft is found throughout the top.

Rain causes the downdraft during this stage, since the downward falling rain traps and entrains air that is carried down. As the cell ages, more and more trapped water is liberated and the downdraft works its way across the base of the cell. The downdraft never reaches to the top of the cell because at high altitudes there is not enough water to produce a significant amount of rain.

The downdraft velocities at this stage vary from 2 o 40 ft. per sec. with the top of the cell up to 25,000 ft.

The cell also changes shape during this stage from a circular to pear-shaped cross section with the updraft in the larger end and the downdraft in the smaller. By the time the downdraft area at the base exceeds the area of the updraft, the cell passes into the dissipating stage.

In the dissipating stage the dominant structural feature is the downdraft that prevails at all but the highest altitudes. Velocities are less than 20 ft. per sec., and the amount of water stored in the cloud has decreased so that only light rain remains below the freezing level. Above the freezing line the snow is also light.

At the very top, 25,000 ft. and up, updrafts prevail, but they are extremely small since little energy of condensation is being realized.

The pear shape of the cell has now reversed with the largest end containing the downdraft. As the updraft dies out the cell again becomes circular.

Summary of Thunderstorm Stages

Each thunderstorm contains cells that may be in any development stage. The majority in any one storm, however, are either at peak or dissipating stages. The cells are turbulent area. The in-between air is calm.

Certain altitudes appear to have a higher rate of occurrence of heavy turbulence than others. The 6,000-

ft. level provides the smoothest ride, while the 14,000- through 20,000-ft. band is, on the whole, the roughest.

The worst time to fly through a cell is between the end of the building and the start of the peak stages. The cell at that stage is in its most turbulent cycle. It is one reason a pilot flying a storm will experience no difficulty, while another (flying the same storm, heading, and altitude 5 min. later) will report severe conditions.

There is no sure-fire means of finding the soft spot, outside of altitude zone, or determining which part of the storm will provide the smoothest ride, either by shape, color, or light or dark spots.

Rain increases with development of a storm from building to peak stages and decreases with a dissipating storm. Downdrafts are caused and maintained by the rain produced within the cell.

It is difficult for the average pilot to determine the stage of development of a storm flown. Although the thunderstorm pilots picked the *correct* development stages 72 per cent of the time, their opinions were based not only from individual appearances but from knowledge of the length of time the storm had been in existence, information not generally available to a pilot on cross-country flight.

Flight Hazards

Turbulence is generally regarded as one of the most dangerous hazards associated with thunderstorm flying because of its effect on the aircraft and the pilot. The disturbed angular motions of an airplane in turbulent air, even with fixed stability and proper piloting technique, are dependent not only upon the maximum intensity of a single gust but also upon the sequence, spacing, and intensity of all gusts encountered.

The sharp-edge gust, with its steep gradient, delivers that solid jolt so familiar to anyone who has flown in rough air. A series of these occurring close together will shake an airplane in a manner comparable to an automobile riding over railroad ties. These gusts, because of their steep gradient, are capable of imposing great stresses upon aircraft. This stress increases with the velocity of the gust and the speed of the airplane. One of the most important factors in the single gust-life of an airplane appears to be the probable speed at which maximum accelerations are experienced.

Drafts are the huge columns of rapidly rising or descending air which comprise an integral part of the thunderstorm's structure. Although the effects of drafts are spectacular from a pilot's point of view, they are not so important with regard to stress loads imposed upon the aircraft.

Draft velocities exceed by a wide margin those of gusts, but since the time interval required to reach the maximum is much greater with the drafts, the acceleration force is far less. Consequently, drafts are not so severe as gusts. However, *attempting to maintain a constant altitude in heavy drafts can easily be a pilot's first step down the road to serious trouble.*

Draft velocities up to 100 ft. per sec. were recorded within the storms flown, and altitude changes were incurred ranging from a loss of 2,000 ft. to a gain of 6,000 ft. The magnitude of altitude change could have been reduced in some instances had the pilot taken altitude correction action. However, the aircraft were always permitted to "ride" the storm. This was desirable not only to permit accurate velocity measurements but to induce proper pilot technique. Attempts to maintain altitude within a thunderstorm may lead to "fighting" the aircraft and a resulting dangerous increase in stress loads.

The magnitude of gusts and drafts varies with the development of the particular cell in which they are contained. Their velocities increase as the cells build into the rain stage and deteriorate throughout the dissipating stage. They will achieve their maximum velocities during the transition from the cumulus to rain stage. Unfortunately, there is no method of predetermining what stage of development a storm is in.

There is often discussed the possibility of a downdraft forcing an aircraft either into the ground or dangerously close to it. The lowest altitude utilized during the project, except for a few isolated 5,000-ft. traverses, was 6,000 ft., and there were no instances where the aircraft at this altitude lost more than 2,000 ft. The downdrafts would subside when the airplane broke clear of the clouds underneath the storm.

The "roll cloud," about which so much has been written, was noted on several flights and traversed without difficulty. It appeared near the 6,000-ft. level, and, since this altitude offered nothing unusual in the way of turbulence, it seems that the roll cloud is undeserving of its nefarious reputation.

Studies on the vertical distribution of gusts and drafts have not yet been completed so their degree of variation with altitude has not been analytically established. On the basis of pilots' reports, certain altitudes seem to contain definite minimums of turbulence. They are scaled from one to six, ranging from extreme to minimum intensity.

(1)	14,000 to 20,000*	Turbulence severe.
(2)	25,000 to 29,000	Turbulence less severe; much snow.
(3)	20,000 to 25,000	Turbulence less severe to moderate.
(4)	10,000 to 14,000	Turbulence occasionally severe, mostly moderate.
(5)	6,000 to 10,000	Turbulence from moderate to light.
(6)	6,000 and below	Turbulence generally light, occasionally moderate.

A general rule of thumb is to stay as low as you can, yet safely clear all terrain obstacles, to avoid the severest turbulence.

Pilot Evaluation of Turbulence

The problem of properly interpreting pilot evaluation of the degree of turbulence is a highly complex one in-

* Above sea level.

TABLE 1

1946					1947					Combined 1946–1947				
Altitude	No. of Runs	Light, %	Moderate, %	Heavy, %	Altitude	No. of Runs	Light, %	Moderate, %	Heavy, %	Altitude	No. of Runs	Light, %	Moderate, %	Heavy, %
26,000	76	56.6	19.7	23.7	25,000	79	45.6	30.4	24.0	25,000	155	50.9	25.2	23.9
21,000	107	51.4	23.4	25.2	20,000	130	35.7	45.4	18.9	20,000	237	43.1	35.4	21.5
16,000	106	50.0	24.5	25.5	15,000	161	32.3	45.3	22.4	15,000	267	38.5	37.1	24.4
11,000	119	48.9	30.2	21.0	10,000	151	29.2	51.6	19.2	10,000	270	37.8	42.2	20.0
6,000	94	68.1	11.7	20.2	6,000	73	46.6	42.5	10.9	6,000	167	58.7	25.1	16.2

volving an almost unlimited number of factors. These factors range from what the pilot had for lunch to whether or not he suffered an early encounter with turbulence by falling out of his crib. Obviously, the greatest single consideration is his degree of experience. Since the same group of pilots were used on both phases of the Thunderstorm Project, it is felt that their opinions are fairly uniform and will provide an idea of the location, degree, and amount of turbulence.

A breakdown of pilot classification of turbulence encountered is given in Table I. This shows the total number of runs classified at each altitude and the percentage of those runs on which light, moderate, or heavy turbulence was encountered. Only the maximum reported was considered on each traverse. Thus, a run on which all three degrees of turbulence were encountered would be considered only in the heavy column. Runs on which no turbulence was encountered have been omitted.

The higher percentage of moderate traverses in the 1947 breakdown is undoubtedly due to the fact that during the initial phase of the 1946 operations only two classifications, light and heavy, were used. This may also account for the somewhat smaller percentage of heavy runs in 1947, although the rising level of experience among the pilots was probably a contributing factor. To date, no thorough studies have been made which might correlate pilot opinion with gust and draft data. Undoubtedly, such a relationship does exist, but the degree of accuracy to which it can be determined remains to be seen.

HAIL

The process of hail formation within a thunderstorm is still largely a matter of theory on which many meteorologists disagree. Information is also sketchy and inconclusive regarding the meteorological conditions most favorable for hail formation. Consequently, there is no reliable method of recognizing in advance a thunderstorm that may provide hailstones. Fortunately, the occurrence of really large hailstones is somewhat of a rarity. Report No. 632, prepared by the Weather Central Division, states: "It appears that one storm in 800 on the Denver–New York Airway produces hail as large as walnuts, and about one in 5,000 provides a small shower of hailstones as large as baseballs. The greatest frequency of large hailstones is found in the Nebraska and eastern Colorado region." Since operations by the Thunderstorm Project were carried on in Florida and Ohio, it is not surprising that no hail of serious consequence was encountered. Damage to the aircraft was limited to punctured deicer boots, dented propeller spinners and intercooler shutters, and battered nose sections. The P-61 is equipped with a composition nose section that is far less durable than the metal used in the rest of the fuselage. This hail damage was annoying to the maintenance section but proved to be no actual hazard in flight.

Hail was encountered on 23 traverses in Florida and on 22 in Ohio. A comparison shows the maximum number of occurrences (12) at 16,000 ft. in Florida, while in Ohio the greatest frequency (10) was at 10,000 ft. The high and low altitudes provided the smallest number of occurrences with two and one, respectively. Only one instance was recorded of hail being encountered in clear air outside the storm. It apparently was falling from the overhanging top of the storm. Generally, hailstones were found well inside the storm and were accompanied by heavy turbulence and precipitation in the form of rain or snow. The preliminary data furnished by these flights do not give conclusive evidence regarding the correlation between the intensity of hail and turbulence. It appears, though, that the two are co-related. This leads to interesting speculation regarding a thunderstorm that would produce hailstones the size of baseballs.

Flight procedures that will minimize the hazard presented by hail appear to be limited to altitude selection. Staying as far below the freezing level as practicable should be the first choice, with a high altitude (25,000 ft. or above) offering the best alternative.

ICING

Wet-snow packing on the leading edges of the wings was experienced during 25 per cent of the total number of traverses. At no time did the accretion build up to more than $1/4$ in. in thickness, and it never presented a flight hazard. Freezing rain coating the wings with a fine film of clear ice, less than $1/16$ in. thick, was reported on five traverses.

The problem of carburetor icing proved more serious than that of ice formation of the aircraft. The danger zone for carburetors seemed to run from 18° to −10°C. free air temperature. In flying through storms, pilots were thoroughly briefed to maintain necessary carburetor heat and constantly check manifold pressures for any tendency to drop, usually the first indication of carburetor icing. It should be remembered, however, that with automatic boost control the throttle butterfly will open to counteract throttling by ice and that considerable icing may occur before any indication is given if the aircraft is flying below the full throttle

height. No cases of engines cutting out or losing enough power to keep from continuing flight because of icing were reported.

Lightning

One of the greatest psychological hazards to the pilot flying through a thunderstorm is getting hit by lightning. The brilliant flash of the discharge, the smell of pungent ozone, the accompanying explosive noise and concussion may frighten even the most experienced pilot.

If the flash occurs at night and the pilot is temporarily blinded, he might find himself trying to fly instruments and seeing nothing but blurred gages.

Moral: Be prepared! When radio static winds up like a wild man twirling a bolo, the indication is that you are approaching an area containing a large concentration of electrical charges that may be triggered off by the aircraft entering the region.

Twenty lightning strikes on aircraft were recorded during the project. All the strikes occurred around and above the freezing level at free-air-temperature readings from $+2°$ to $-25°$C.

An N.A.C.A. report summarizing the frequency of lightning strikes on aircraft relative to time of day and free air temperatures indicates that "there is a broad maximum in the frequency of disruptive charges to aircraft in the first 9 hours after noon and a broad minimum in the first 9 hours after midnight, local standard time. The region most frequently the scene of discharges is in the 20° to 40°F. temperature layer."

The report also pointed out that "cloud-to-ground strokes are most frequent in the earlier stages of an active thunderstorm. As the storm ages, the strokes become predominantly intracloud strokes and keep diminishing in frequency."

No major damage by lightning was experienced by the P-61 thunderstorm aircraft. However, lightning strikes burned off radio antennas and static discharge wicks; drilled holes up the size of a dime in wing tips, rudders, and elevators; and bent one air-speed pitot head 15° from the horizontal. In that particular instance, the pilot reported he was flying through a thunderstorm at 26,000 ft. in heavy snow. "Radio static kept building in intensity until it was so severe that I couldn't keep the earphones close to my ears. I heard what sounded like the sharp burst of a German 88 mm. A sheet of flame simultaneously enveloped the entire cockpit. My air-speed indicator jumped from 190 to 500 and stayed there. Everything looked a bit fuzzy.

"The air was so turbulent and the instruments jumped around so much that I couldn't tell for a moment what was going on. I just let the airplane buck through. After what seemed hours, the air-speed came back to normal." (Film records showed that the air-speed indicator maintained an erroneous 500 m.p.h. reading for approximately 30 sec.) The radar operator who did not have dark goggles over his eyes said he was unable to read his panel for "about 2 min."

No aircraft radio failures from lightning strikes were recorded. This may have been due to heaving bonding and shielding installed on all of the project aircraft. Standard V.H.F. ARC-3 and radio compass and low-band command receivers were used.

N.A.C.A. studies indicate that before any aircraft can be struck there must be a region where a large concentration of charges exist and that at some point near that region the potential gradient must reach a magnitude that exceeds the critical sparking value of 1,000,000 volts per m. at normal air density in the presence of large cloud droplets.

All metal aircraft properly bonded act like a Faraday cage. The metallic structure acts as a shield to shunt any discharge current around the occupant. Consequently, there can be little difference of potential between points on the bonded metal surface of the plane.

A considerable difference of potential may exist in radio equipment when charges are conveyed into the aircraft by the aerial, but the maximum difference that may be effective outside of that is greatly limited by the insulation strength in the radio or by the lightning arrester gap. Therefore, it does not seem likely that a direct lightning hit will seriously injure the aircraft occupants unless there is deficient bonding of metallic parts.

Where bonding is defective or lacking or where the aircraft is constructed of nonconducting materials (wood and fabric), large differences of potential may be established during a thunderstorm, creating a definite hazard to both occupants and aircraft. Disruptive effects occur where nonconducting materials are involved. Fires may be caused because of faulty bonding and fatal electrical shocks obtained.

Effect of Speed Relative to Strikes

There seems to be a correlation between the speed of the aircraft and the frequency of strikes incurred. Seventy-two per cent of the strikes occurred above 180 m.p.h.

The N.A.C.A. analysis indicates that the faster an airplane travels through a thunderstorm, the more rapid is the rate at which it will produce and acquire charges. This charge accumulation increases with the square of the speed. If air speed is increased from 180 to 200 m.p.h., the total charge pickup will rise 25 per cent. As the total corona current and intensity of precipitation static increase with speed, conditions become more favorable for a possible hit.

An aircraft flying through a thunderstorm is not likely to be struck unless preceded by moderate or severe precipitation static or St. Elmo's fire (corona). This corona discharge takes place only from a given point when the potential gradient in the air adjacent to the point reaches a critical value.

When a plane flies through an area of charged precipitation of cloud particles, its motion, relative to the

particles, forces them to be driven together and to coalesce. This forced coalescence of like-charged water drops, snow, or hail gives the merged particles a greater potential than the smaller ones originally present.

As the speed of the aircraft keeps increasing, the ram action of the plane crowds the particles into a smaller space and intensifies the potential gradient. The greater the speed, the more pronounced are these effects, and more particles will be brought within the sphere of the plane, thus increasing the possibility of strike incurrence.

Summary of Flight Hazards

Reduce air speed; this reduction allows charges to fall off and permits corona discharges to diminish in intensity.

If precipitation static or St. Elmo's fire is severe and outside air temperature is between $-25°$ and $+2°$C., fly out of that zone. Seek a level above or below that temperature band.

Cloud-to-ground strokes indicate early stages of an active thunderstorm. As the storm diminishes, strokes become predominantly intracloud.

If aircraft is equipped with trailing antennas, make sure it is reeled in.

Turn cockpit lights full bright or put on dark goggles. Do not keep phones too close to ears. It will prevent possible acoustic shock.

The tendency for St. Elmo's fire and precipitation static sounds to build up rapidly in intensity should be regarded as a preliminary warning that a discharge may be imminent.

Conclusions

Pilot Technique

Most routine flight operations throughout the Air Force require a certain amount of thunderstorm flying. It is not always possible to avoid storm areas. At night it is often impossible to detect individual storms and find the in-between clear regions. At other times it is impractical to detour a storm line, and the only alternative is to go through.

With a radar-equipped aircraft, an appreciable reduction in gust experience can be achieved by circumnavigation of radar echoes caused by thunderstorms. On the basis of preliminary data, a considerable difference exists in the average magnitude and spacing of gusts within and outside of radar echoes.

The mean velocity for gusts encountered within the radar echo is about 12 per cent greater than the mean gust velocity outside of the 2-mile range of radar echoes.

The average spacing between gusts varied from 0.204 mile inside the echoes to 0.566 mile for the zone outside the 2-mile radius. It appears that the region of radar echoes is considerably more turbulent than the surrounding areas. The number of gusts per 1,000 gusts over 20 ft. per sec. varied from 18 for the radar echoes to two for the zone outside the 2-mile radius.

But what about nonradar equipped airplanes? Tactical-type aircraft can structurally fly through most thunderstorms provided a reasonable attitude and speed is maintained. One of the primary factors in structural failure is loss of control resulting from a stall followed by a high-speed recovery.

The things to remember are: (1) *the airplane must be readied before penetration;* (2) *fly attitude.*

Thunderstorms telegraph their proximity by radio crash static. When this condition exists, the pilot must slow down to the best penetration speed and constantly keep the aircraft prepared, even if it does seem silly, for long periods. This must be done in advance.

He should check his instruments, lights, pitot and carburetor heat, deicing and oxygen equipment, safety belts, mixture, r.p.m.'s, manifold pressures, etc. By the time he hits the storm he knows everything is ready. This is important because it is the pilot's first safety valve and gets him set for the actual entry.

The danger in being unprepared is when the aircraft is on instruments and the pilot accidentally flies into one and "everything happens at once."

Once in the storm, a relatively level attitude must be maintained. Thunderstorms must be flown primarily with gyro instruments and the air speed. Barometric instruments give false readings because of rapid changes of pressure encountered in the storm.

Concentrate principally on keeping a level attitude by the gyro horizon. This means you may gain or lose several thousand feet and your altitude goes by the wayside, but, by using as little elevator control as possible to maintain that attitude, you can ride the severest storm with a minimum amount of stress imposed upon the aircraft.

Do not "chase" air speed. It will result, especially in high-speed and heavy aircraft, in excessive attitudes, and it is easy to visualize the result of the nose being high and a sudden gust increasing the angle of attack to a stall. Use throttles only when the high or low limits are exceeded. Remember that heavy rain may slow down the indicated air-speed reading up to 70 m.p.h. because of partial blocking of air entrance.

This attitude-flying technique is possible as long as the gyros do not spill. If this occurs, the pilot may find himself in a difficult position trying to keep reasonably level on the needle-ball-air-speed primary group.

Not one single case of a flight gyro tumbling during thunderstorm penetrations was reported during the entire project. Every standard-type flight horizon, both vacuum and electric, was used with the same results.

Summary

Get the airplane "ready" for penetration well in advance.

Maintain level attitude. Do not correct for altitude gained or lost from up or down currents unless absolutely necessary to clear obstructions on course. Use as little elevator control as possible.

Use throttles only if exceeding high or low limits.

Attitude and speed should be the primary function; altitude, the last.

Flight Procedures Through Thunderstorms

The flights conducted by the Thunderstorm Project offer conclusive proof that a pilot using modern equipment and possessing a combination of proper experience, common sense, and instrument-flying proficiency may safely fly thunderstorms.

To ensure the successful completion of such flights, certain procedures, listed below, must be followed.

Before take-off: (1) Check Thunderstorm Scale for best penetration speed. (2) Make a thorough analysis of the weather situation to determine the possible and probable location of thunderstorms.* (3) Prepare flight plan, making intelligent use of information gained in weather analysis. (4) Try to select the "softer" altitudes. (5) Make a complete check of aircraft to ensure proper operation of all flight instruments, radio and navigation equipment, pitot and carburetor heat, panel lights, oxygen, safety belts, wing and propeller deicers and anti-icers, etc.

Approaching the storm: (1) Get airplane "ready." (2) Slow down to penetration speed. Increase r.p.m. for gyroscopic stability. If flying jet aircraft, extend dive flaps; this will tend to keep the airplane from quickly picking up too much speed in unusual attitudes. (3) Mixtures rich. Pitot and carburetor heat on. (4) Uncage gyro instruments and check for proper settings. Check vacuum pressure, and make mental note where pump switch is located. (5) Be sure altitude control is turned off if autopilot is being used. (6) Tighten safety belts. (7) Turn off any radio equipment rendered useless by static.† Make sure trailing antennas are reeled in. (8) If at night, turn cockpit lights full bright or put on dark glasses to minimize blinding effect of lightning.

In the storm: (1) Devote all attention to flying the aircraft. (2) *Expect* turbulence, precipitation, lightning, etc., and do not allow them to cause undue concern. (3) Use proper control technique (see section on "Pilot Technique"). (4) Maintain original heading—it's the quickest way out. Don't make any turns unless absolutely necessary. (5) Remember that sound planning, proper procedures, plus common sense and an intelligent outlook will see you safely through.

Although only one 43-ft. gust was recorded during the project, it is reasonable to assume that one of similar intensity will be encountered by some pilot at some time. During the 38 missions flown in 1946, the average maximum gust velocity was 24.3 ft. per sec., and only seven flights provided velocities of 30 ft. per sec. or greater. Figures for the 1947 operations indicate that the average maximum gust approximates 30 ft. per sec.

* Thunderstorms are tricky to forecast, especially at night.

† During the project it was found that V.H.F. radio equipment was unaffected by electrical disturbances within the thunderstorm.

What then is the average pilot's probability of encountering the larger values of gust velocities in traversing thunderstorms? Determining these probabilities becomes a statistical problem of considerable complexity, since these methods are still in development stage and present estimates are considered preliminary.

N.A.C.A. estimates indicate that a 43 ft. per sec. gust might be experienced once in every 1,000 traverses; 40 ft. per sec., once in 500 to 700; 35 ft. per sec., once in 125 to 300; 30 ft. per sec., once in 35 to 100.

Breaking it down still further, it would take some 10,000,000 flight-miles to exceed the highest recorded gust. Assuming a cruising speed of 200 m.p.h., it might be expected that the limit could be reached once on the average in every 50,000 hours of flight. Since the Air Force logs approximately 10,000 hours of flight daily throughout the world, this gust might be experienced once every 6 or 7 days.

These large gusts generally produce linear accelerations of the whole airplane, along with pronounced displacements in roll, yaw, and pitch. These manifestations may be single or multiple; considerable time may elapse between principal disturbance or several disturbances may follow each other within a few seconds.

Maximum accelerations can be attained if the transition zone between adjacent and parallel currents of different velocities have zero thickness. When an aircraft goes abruptly from calm air to a vertical current at right angles to its path, the condition is a sharp-edge gust. If the transition zone is above zero, it is possible to exceed design loads in thunderstorm and squall conditions.

However, in a sharp turbulent transition zone between the most violent updrafts and downdrafts, the destructive force of accelerations upon structures may reach such proportions as to make flight within those regions hazardous.

There is danger of flying certain type aircraft (cargo, passenger, etc.) at high speed through heavy turbulent areas, for the imposed wing loadings may exceed safe limits and impose dangerous strains on aircraft structures. Reduction in speed prevents wing loadings from reaching excessive values.

A heavily loaded airplane is subjected to a greater total wing load than a lightly loaded one of the same type. Accordingly, a gust that may be safely endured by the wings of a lightly loaded plane because of its acceleration response, might induce critical or destructive loads upon a heavily loaded one that responds less readily to gusts.

Since lightly loaded airplanes undergo higher accelerations than heavily loaded ones, supports of fixed-weight structures like nacelles are subjected to greater stresses in lightly loaded ships.

This creates an objection to operation of lightly loaded airplanes at higher gust velocities, since the supports may not be able to stand the more intense stresses imposed by stronger accelerations.

In order to obtain a scale enabling a pilot to determine the best air-speed zone, calibrated in IAS, to traverse

the storm while still on the ground, a 43-ft. gust line was plotted on the airplane *V-G* diagram, and the values recorded are at the intersections of this gust line with the maximum lift and maneuver lines. The same was worked out for the average 30-ft. gust. An additional 10 per cent safety leeway was included to cover pilot amplification of control. The thunderstorm penetration speed scale for all cargo- and tactical-type aircraft is classified and cannot be published.

Recommendations

In reviewing the various "mechanical" hazards associated with thunderstorm flying, it is found that they are turbulence, lightning, hail, and icing. Not one of these is in itself extremely dangerous. A most prevalent danger in a thunderstorm is the mental hazard.

In educating pilots to fly thunderstorms, there must be a psychological softening-up process to eliminate the age-old bugaboo about the invincibility of the cumulonimbus. A thunderstorm might appear awe-inspiring, but with the proper aircraft and techniques it can be traversed without undue difficulty.

Pilots must be taught that calmness is a primary factor and that by erasing fear they keep their ability to think and use the maximum amount of skill. Once fear begins to cloud the pilot's mind, turbulence, precipitation, lightning, etc., seemingly increase.

The reduction of mental strain upon the pilot through enlightenment, proper training, and experience holds forth the greatest promise for safe thunderstorm flying in the immediate future.

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Operating Problems of Turbine-Powered Aircraft

R. D. KELLY*
United Air Lines, Inc.

THE EVENTUAL APPLICATION of turbine power plants to commercial operations is inevitable. Reports of individuals who have had an opportunity to ride in turbine-powered transport aircraft have left little doubt but that the smoothness and quietness of such aircraft will have definite passenger appeal.

It also seems certain that the speed advantage of turbine-powered aircraft will be sizable, whether they be pure jet or turboprop propelled. However, the higher speed of these new airplanes is not significant for short-range operations if the aircraft must climb to high altitudes to achieve that speed and if the ramp, taxi, and runup times are high in proportion to the flight time.

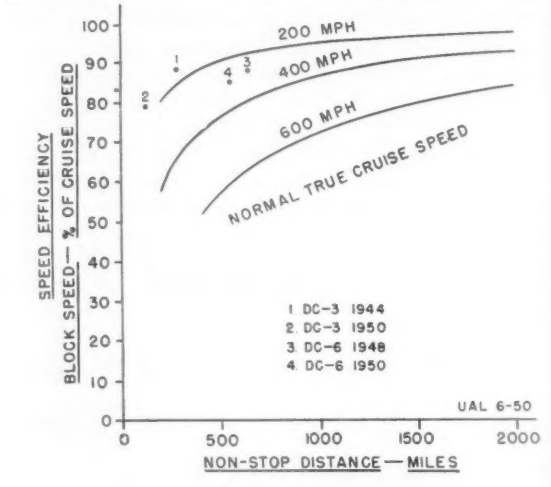
Fig. 1, labeled "Speed Efficiency," was constructed from the best data available to show the approximate percentage of cruising speed convertible to "block-to-block" speed. It can be seen that the faster airplane (600 m.p.h.) is penalized greatly, especially over the shorter distances, by the extra time required to climb to, and descend from, its higher normal cruising altitude.

Fig. 2 is a similar chart, showing actual values of block speeds vs. nonstop distance for three new intermediate-range types of aircraft. The turbojet airplane has an increasing advantage speedwise as the nonstop distance approaches the absolute range. The turboprop-powered craft shows up to some advantage over the reciprocating-engined craft at the shorter distances. It is my opinion that the turboprop airplane can and should be designed for a higher speed than shown for this one (305 m.p.h.) in order that it can better compete speedwise with the full jet. It is believed that a reasonable increase in speed for it would also result in better economy.

Perhaps a better way to look at the competitive speed picture is to compare the airplanes on a "block time" basis. This is shown on Fig. 3 for the three airplanes under discussion. The timesaving ability of the jet airplane over the reciprocating-engined craft is more impressive for the longer distance. For example, the 43-min. saving on the Chicago–LaGuardia segment is very real, whereas the 17-min. saving on the Los Angeles–San Francisco stage (about the average time required to get one's luggage) is not likely to justify any great fare differential. This chart also demonstrates the need for a higher speed turboprop aircraft if it is to compete with the jet.

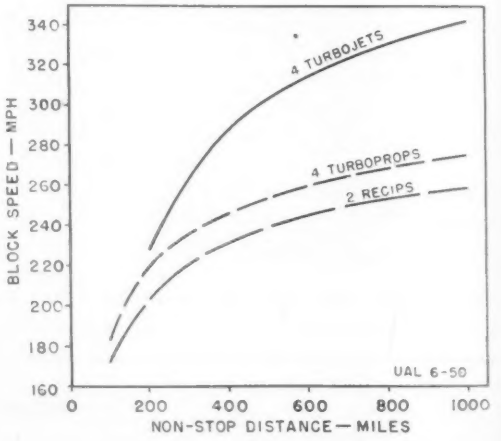
Presented at the Session on Turbine-Powered Aircraft, Annual Summer Meeting, I.A.S., Los Angeles, July 12–14, 1950.

* Superintendent of Technical Development.



NOTE: TAXI, CLIMB & DESCENT TIMES
200 M.P.H. AIRPLANE ≡ 30 MIN. AT 100 M.P.H.
400 M.P.H. AIRPLANE ≡ 45 MIN. AT 200 M.P.H.
600 M.P.H. AIRPLANE ≡ 75 MIN. AT 300 M.P.H.

FIG. 1. Speed efficiency.



AIRPLANE	CRUISE SPEED MPH	CRUISE ALTITUDE FEET	CRUISE POWER NRP	TAXI & RUN-UP TIME MIN
4 TURBOJETS	395	30,000	90%	11
4 TURBOPROPS	305	24,000	90%	8
2 RECIPS	280	18,000	67%	8

FIG. 2. Intermediate range. Block speed comparison. Zero wind.

The economic advantages of speed may be sufficient to bring the overall operating costs of turbine-powered transports down to as low a level as can be achieved by present-day reciprocating-powered transports. Fig. 4 has been constructed using the above modern medium-range two-engined reciprocating aircraft as a basis. In this chart, the cost of operation of this airplane per available ton-mile for varying nonstop distances is taken as 100 per cent. The full jet aircraft and the turboprop-powered aircraft, both carrying substantially the same pay load as the reciprocating-engined craft, have been used for comparison. While these three airplanes are not directly competitive in many respects, it is self-evident that for some route segment lengths the costs per ton-mile are directly competitive. The full jet airplane is uneconomical for the shorter distances, and the turboprop achieves the lowest cost per ton-mile over most of the ranges. This same chart also illustrates the great influence fuel cost has on the overall economy of turbine-powered transports.

If the turbine-powered aircraft are to be preferred from the standpoint of passenger comfort and speed and if their costs are at least competitive, why are we not moving into a replacement program more rapidly?

The first answer to this is "human inertia." With the large number of individuals and agencies involved in the approval and execution of a replacement program of costly and complicated civil passenger and cargo airplanes, it is not possible to expect a complete and rapid changeover. This is a business and political problem, not a technical one.

Another important factor is what is known as "cost of introduction." Experience with every new model of airplane has shown extremely high costs associated with its introduction, even though the changes may not have been drastically different from previous designs. These costs have been due to training, elimination of hazards, lack of dependability, modification programs, etc. No airplane has ever been satisfactory until it has progressed through an expensive and difficult "learning" or service-test program. Certainly, the same sort of experience must be anticipated for turbine-powered aircraft, whether or not the aerodynamics of the machine are greatly altered. Altered aerodynamics will only tend to increase the degree of cost and lengthen the time.

It should be self-evident that any transportation system that does not achieve a high degree of schedule reliability is not a good transportation system. Unreliability of service can soon destroy all of the advantages of speed of air travel. The air-transport industry for many years tried to sell speed rather than dependability, and in many cases this backfired because the service could not be relied upon. Only within the past few years have the air lines been able to overcome this lack of dependability to a point where their service is directly competitive with other means of public transportation. It would be most unfortunate at this time if the air lines, under the spell of still higher maximum speeds obtainable under optimum conditions with turbine power plants, failed to give due emphasis to continuing and further improving schedule reliability with the newer and faster aircraft now on the horizon.

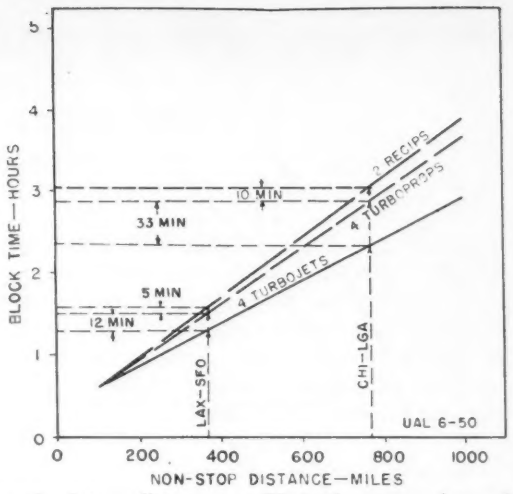


FIG 3. Intermediate range. Block time comparison. Zero wind.

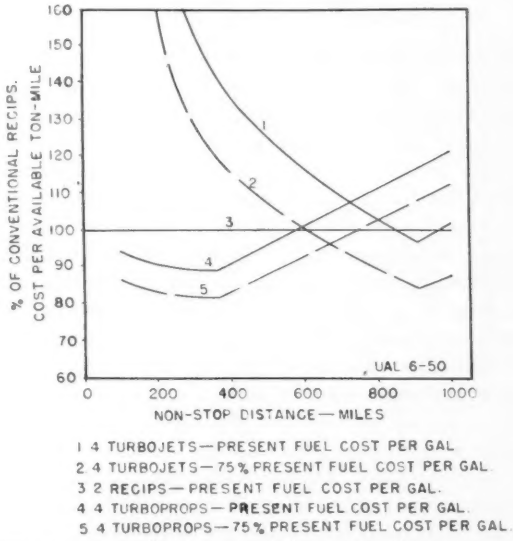

% OF CONVENTIONAL RECIPS. COST PER AVAILABLE TON-MILE
NON-STOP DISTANCE—MILES
UAL 6-50
1 4 TURBOJETS—PRESENT FUEL COST PER GAL.
2 4 TURBOJETS—75% PRESENT FUEL COST PER GAL.
3 2 RECIPS—PRESENT FUEL COST PER GAL.
4 4 TURBOPROPS—PRESENT FUEL COST PER GAL.
5 4 TURBOPROPS—75% PRESENT FUEL COST PER GAL.

FIG. 4. Intermediate range. Direct operating expense per available ton-mile. Zero wind.

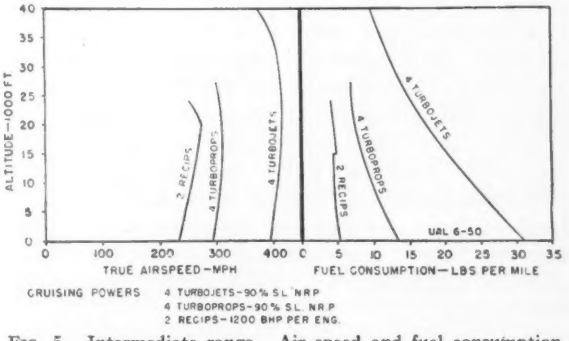


FIG. 5. Intermediate range. Air speed and fuel consumption vs. flight altitude. Zero wind.

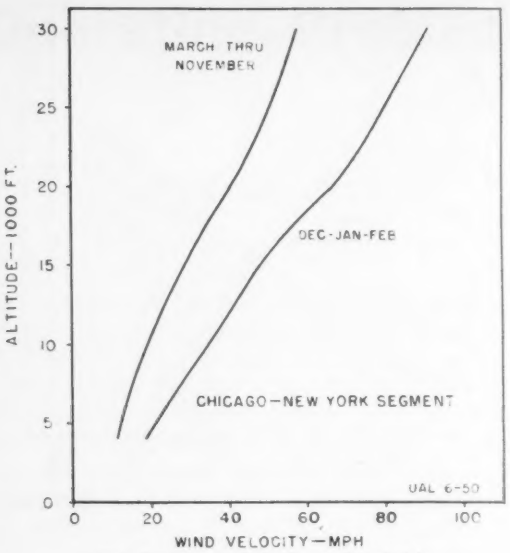


FIG. 6. Mean winds (westerly winds).

Therefore, the cruising speeds quoted for the newer aircraft are not the figures to be emphasized. The actual block-to-block time that can be guaranteed and maintained day in and day out is of much greater importance to the customer. Recently, one individual pointed out to me that a still better measure of our transportation service would be to quote times on a "luggage-to-luggage" basis. Perhaps he has a point.

The need for taking the variable wind conditions into consideration in the operation of turbine aircraft has often been stressed. With the increasing evidence that extremely high velocities will be frequently encountered at high altitudes and over certain routes, it now becomes a major problem for the air-line operator to attempt to anticipate what this will mean in operating over various stage lengths while maintaining good schedule reliability. The much higher fuel consumption per mile, particularly with the full jet craft, brings the wind factor into greater prominence, because range, pay load, and block speed are all affected.

Fig. 5 compares these airplanes from a fuel consumption standpoint and speed over the normal range of altitudes. This graphically illustrates why pure jets are cruised at high altitudes and why they are so uneconomical during climbs and holding at low altitudes.

So far, all of these comparisons have been for the zero wind condition—which never actually exists. Better comparisons can be made if "typical" or "mean" head winds are injected into the calculations. Even then the "worst" headwind condition must not be forgotten as a possibility—but it has not been included in this analysis.

Fig. 6 shows the mean westerly winds that existed above the Chicago–New York run in 1946–1947 for the winter period (December, January, and February) and also during the preceding part of the year 1946. These are plotted to show the wind velocity gradient that existed with altitude and form the basis for analyzing the effect of these winter westerlies on the aircraft under discussion. It was particularly desired to learn the influence of changing flight altitudes, with each of these airplanes, when confronted with the mean winter head winds shown in Fig. 6. The speeds and fuel consumptions shown in Fig. 5 were used as a basis of comparison to illustrate the effects caused by head winds encountered at various altitudes.

Fig. 7 is the result. Generalizations from this figure are:

(1) Accurate knowledge of winds aloft is essential to the best utilization of any type of aircraft, but with the higher flying turboprops and turbojets it becomes doubly important in the interest of maintaining dependable schedules and reducing costs.

(2) The reciprocating-engined aircraft is less able to cope with winds in maintaining schedules, but its increased fuel consumption when attempting to make the best possible speed is less than for the turbine power plants.

(3) By reducing altitude, the turbojet is theoretically most capable of maintaining schedule speed in the face of adverse winds, but the enormous increase in fuel consumption drastically reduces range or pay load. Further, the structural limitations of the craft or the passenger discomfort may rule out low-altitude operation.

(4) The turboprop represents an attractive compromise, probably permitting the maintenance of the most dependable service without undue fuel cost penalties.

(5) Speeds more nearly equal to that of the jet would further enhance this ability of the turboprop used in this study.

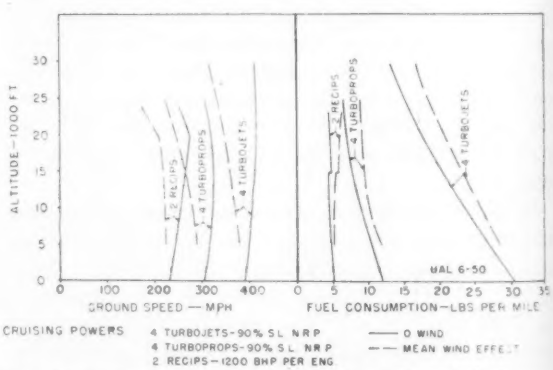


FIG. 7. Intermediate range. Ground speed and fuel consumption as affected by head winds.

Aircraft Flight Testing in Miniature

J. E. MURPHY* and M. V. MORKOVIN†
University of Michigan

IN JUNE, 1948, the Department of Aeronautical Engineering at the University of Michigan reached a decision to institute a senior laboratory course in Flight Testing in order to round out the undergraduate curriculum. The resulting analysis of financial and technical feasibility of such a course led to the acquisition of a four-place Navion early in 1949. With this aircraft as basic equipment, the course has now been successfully offered every semester since the Fall of 1949. It is the purpose of this paper to review the organization and achievement of this course, identified as A.E. 176.

The undergraduate in aeronautical engineering receives instruction in theory, design, and in wind-tunnel and structural testing. The concept of A.E. 176 was to have the otherwise adequately prepared senior come into contact with the final product of his profession with the following aims:

(1) To give an understanding of the problems connected with gathering of data in the air and the methods and equipment used for their solution.

(2) To familiarize the student with the scope and limitations of flight testing considered as an engineer's tool.

(3) To give the student an idea of the pilot's point of view with regard to handling characteristics, interior arrangement, seating visibility, lighting, instrument arrangement, etc.

(4) To make concrete the concepts learned in other courses.

To emphasize the level of the work, a prerequisite of the senior course in Performance, Stability, and Control was established.

When one considers the facilities and budget of industrial or Governmental flight testing divisons, it is clear that many limitations face such an endeavor at an academic institution. The main boundaries for the present effort were set by limited funds, by the necessity of satisfying C.A.A. regulations for NC commercial aircraft designation, and by the limitations of weight and space in the airplane. The flight-test specialist would undoubtedly like to see these restrictions relaxed. However, it is believed that the *experience* and *attitude* that the student builds up with the aid of this miniature facility represents the major asset of which the specialist will approve.

The course is covered in a 1-hour lecture and one 3-hour laboratory period per week for 2 semester-hours of credit. The laboratory sections consist of six students each; in those sections that involve flying, three students are aloft, while the other three perform analytical work. It was found best to have the instructor present the academic work and act as "test pilot" during the flight periods as well. In this manner, closest correlation between the lecture material and the experimental work is achieved.

Weather permitting, the scheduled course work consists of seven to eight flight periods alternating with six to seven analysis and calibration periods. Of course, the lecture material covers not only the background for the actual tests that are run but includes ample discussion of most of the current methods necessary for the flight evaluation of prototype aircraft. In this way the students acquire an appreciation of the scope of the testing program as actually carried on in a typical flight-test section. The lecture material is based on generally available literature and on reports describing methods employed by the Navy, Air Force, Douglas Aircraft Company, Inc., North American Aviation, Inc., Bell Aircraft Corporation, Curtiss-Wright Corporation, and Chance Vought Aircraft Division of United Aircraft Corporation. The cooperation of the above-named Services and companies is gratefully acknowledged.

At the present time, the instrumentation allows for the following flight tests: (1) Familiarization Flight (general aircraft operation and attitude control; qualitative runs). (2) Determination of position error by the speed-course method. (3) Best speed—best power level flight runs (2 periods). (4) Determination of climb performance (2 periods). (5) Determination of fixed-stick static stability. (6) Determination of free-stick static stability.

During the above runs there is time to introduce short qualitative tests demonstrating the effects of propeller pitch on take-off and climb performance and effects of power on stability. Dynamic aircraft behavior, such as phugoid motion and response to sudden control deflections (step-function type), is also easily illustrated.

The present instrumentation (most of it "home-built" or renovated from war surplus) includes a sensitive air-speed indicator, a sensitive altimeter, and a vertical-speed indicator mounted in an auxiliary instrument panel at eye-level position directly in front of the pilot. The standard Navion tachometer was replaced with a sensitive electrical, generator-indicator-type tachometer. An outside air-temperature pickup was installed under the port wing, with a sensitive indicator on the instrument panel. Elevator deflections are

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† Associate Professor, Department of Aeronautical Engineering.

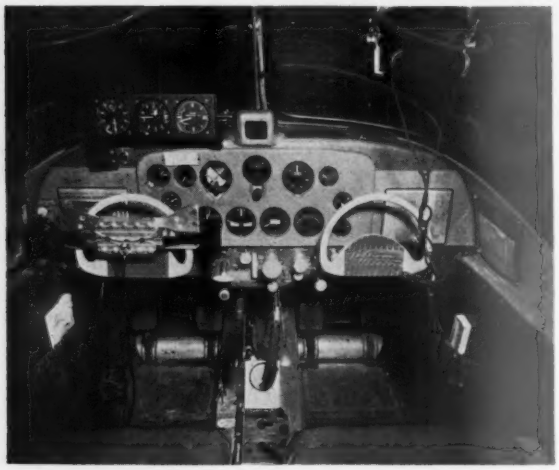

FIG. 1. Present instrument panel and the wheel-force indicator as installed for testing.

measured by means of an autosyn transmitter attached to an elevator hinge bolt through a 1:5 gear train; the deflections are read on a radio compass indicator located on the instrument panel. A special strain-gage-type wheel-force indicator, which clamps directly onto the control wheel (without requiring control system modification), was designed and constructed (see Fig. 1). Strain of a cantilever beam is read on a Young portable strain recorder and translated into control force by means of a calibration curve.

All the instruments, with the exception of the wheel-force indicator are duplicated in a photorecorder located in the baggage compartment. All connections to the recorder were made of the "quick-disconnect" type, so that the recorder can be quickly removed from the aircraft should it be needed for transportation. The students are asked to take all data visually to impress upon them the frailty of "human recorders," to give them an appreciation of what is going on during the runs, and to provide a check on proper functioning of instruments. Some rough data reduction is done during flight so that any questionable runs can be repeated immediately.

At present, the method for evaluation of airplane performance depends upon the utilization of the engine manufacturer's power charts and could be improved by the use of an accurate torquemeter and fuel flowmeter. Unfortunately, installation of a torquemeter on small, direct-drive engines presents great difficulties. An accurate flowmeter was ruled out on the grounds of expense and excessive weight.

In view of the limited instrumentation, the repeatability of the data has been gratifying. Also, the check with manufacturer's performance tests was found satisfactory.

The first laboratory period is spent calibrating the air-speed indicator, the altimeter, and the tachometer, with emphasis on the appreciation of the error sources and methods used in correcting for them. It was found that a surplus Instrument Test Set, Type C-1, greatly facilitated the calibration of the air-speed indicator and the tachometer, although additional and more accurate calibrating instruments (stroboscope, sensitive manometers) were borrowed for the purpose.

It is perhaps in order to mention here a few of the experiences more peculiar to the light-airplane testing or more impressive to the student. An appreciation of the effects of a small c.g. shift upon trim was gained when the students noticed that they could change the level flight trim speed by merely leaning forward in their seats. This also illustrated the importance of pilot technique needed for achievement of good test-runs. Large discrepancies in random-gathered climb data demonstrated the effects of vertical velocity gradients and unstable temperature-lapse rates upon the climb-performance determination. It is sometimes stated that power effects on stability become important only for highly powered aircraft; data in Fig. 2 illustrate vividly to the student the differences in stability and trim between power-off glides and level runs. A demonstration of the full-flaps power-off gliding angle and of the destabilizing effects connected with subsequent application of power constitutes another worth-while experiment from the student's point of view.

That safe operation is an item of paramount importance is impressed on the student from the outset of the course. A typical set of rules for flight-ramp conduct is presented in the first lecture and is supplemented by the instructor-pilot by repeated appropriate comments during flight periods, both on and off the ground. (In flight, safety presents no problems, because the students are kept busy recording and checking data; however, on the ground, the turning propeller is a hazard that requires constant vigilance.) Rigorous maintenance of the aircraft is provided by experienced and competent personnel in the shop of the University of Michigan Aeronautical Research Center at Willow Run Airport. Since the airplane is flown within placard limitations, it always retains its NC (commercially certified) designation, and normal insurance coverage for occupants and property applies. Despite the meticulous observance of safety precautions, the

(*Continued on page 35*)

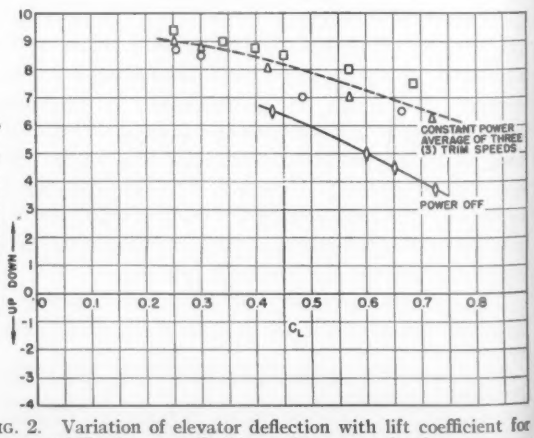

FIG. 2. Variation of elevator deflection with lift coefficient for stabilized power-off glides and power-on level runs.

Jet Nozzles for Aircraft Gas Turbines

W. O. MECKLEY*
General Electric Company

ONE OF THE MOST IMPORTANT FUNCTIONAL ITEMS on a turbojet engine and yet one that is least written about or discussed is the jet nozzle. The jet nozzle accomplishes the last gas expansion in the gas turbine cycle, as shown in Fig. 1. In a turbojet unit it is the final conversion unit in the system—that is, it is the mechanism for converting pressure energy into velocity or thrust energy. This is an important item in the case of a turbojet where thrust is the sole propulsive output.

(A) Fixed-Area Jet Nozzles

Probably the reason little has been said about jet nozzles is the relative simplicity of the device in most turbojet units that are flying today (see Fig. 2). The most common jet-nozzle design now in use is simply a straight conical nozzle with a fixed area. A number of minor variations from the simple conical-shaped nozzle have been made in an effort to achieve higher nozzle efficiencies. Nozzle shapes with curved or bellmouth entries and conical shapes with small included angle are typical of these variations (see Fig. 3). It has been found that, in general, the gain in output with these alternate designs does not justify the added complication of installation and manufacture.

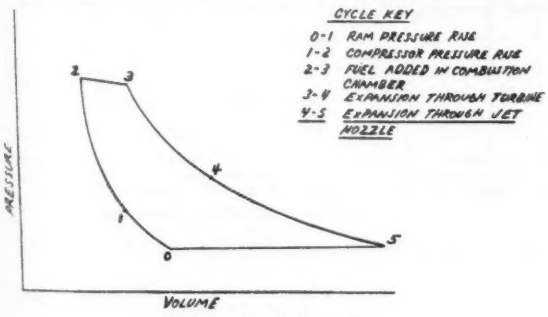

FIG. 1. Turbojet cycle.

FIG. 2. Republic XP-84 airplane equipped with G-E aircraft axial-flow gas turbine, type TG-180, in flight. Right-side view oblique from below; nose at right.; jet nozzle at left.

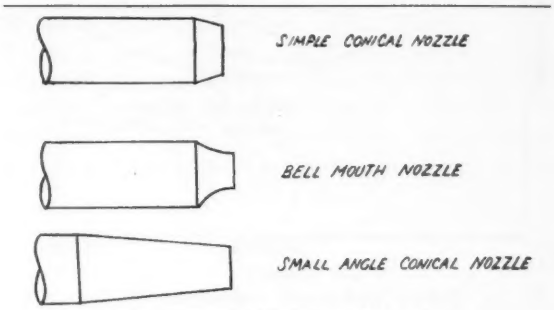

FIG. 3. Types of fixed-area jet nozzles.

(B) Variable-Area Jet Nozzles

A promising development in turbojet design is the substitution of a variable-area jet nozzle for the fixed-area jet nozzle. A jet nozzle with variable area and properly integrated control should (1) give better fuel economy during cruising operation, (2) provide more rapid thrust increases during an engine acceleration, (3) permit cooler starts, and (4) compensate for thrust variation among engines so that all turbojets in a multiengined airplane will deliver equal thrust.

The thrust of a turbojet can be decreased approximately one-half by doubling the nozzle area at a fixed turbine speed. This enables the turbojet unit to operate more nearly on its point of maximum efficiency, thus achieving better fuel economy in cruising flight. For some turbojet units this gain is about 3 or 4 per cent (see Fig. 4).

The variable-area nozzle, by virtue of its ability to vary thrust output, enables operation at full engine speed. If thrust is required in an emergency, such as might be encountered in the event of a pilot error in landing, the jet nozzle can be partially closed almost instantaneously, resulting in an immediate increase in thrust without having to wait for the relatively slow acceleration of the turbojet rotor as would be the case with a fixed nozzle.

A variable-area nozzle will enable engines to be started with lower turbine discharge temperatures, thus increasing turbojet life. The jet nozzle can be in its wide-open position during engine starts, so that, even if excess fuel is applied during a starting sequence, the jet nozzle area will not offer enough restriction to overtemperature the turbines except in extreme cases, as is sometimes encountered with fixed-area nozzles.

The task of compensating for thrust variations among turbojet engines in a multiengined airplane is

* Aircraft Gas Turbine Divisions.

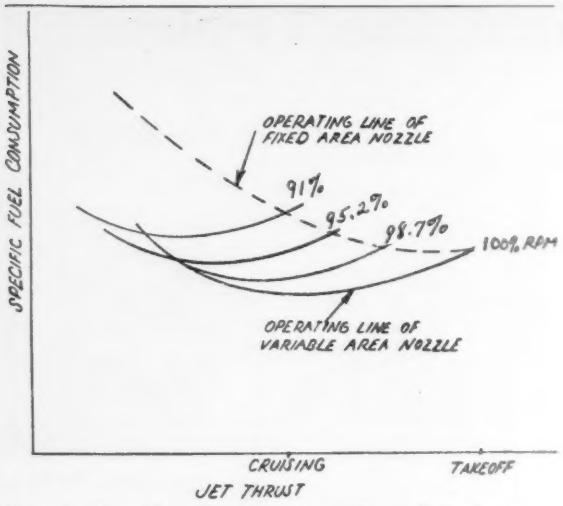

FIG. 4. General performance comparison of fixed- versus variable-area nozzle installed on turbojet.

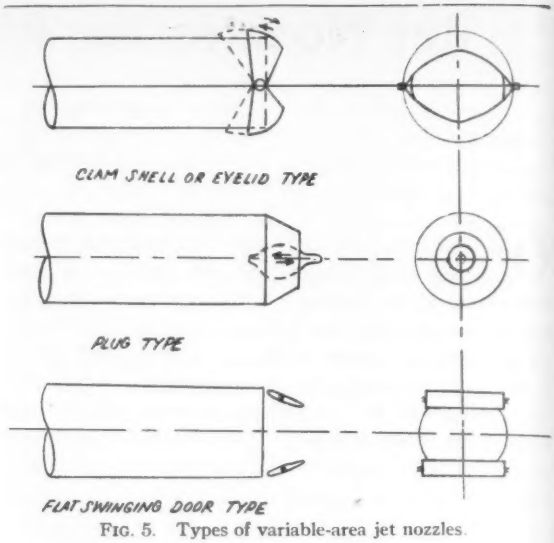

FIG. 5. Types of variable-area jet nozzles.

usually accomplished by physically modifying the jet-nozzle area so that all of the effective minimum areas are evenly matched. This matching may have to be done with each engine change and is, in general, somewhat unsatisfactory. With a variable-area nozzle, thrust adjustment may be made by a properly integrated control in the pilot's cockpit.

The general types of variable-area jet nozzles under consideration are (1) "clam-shell" or "eyelid" type, (2) plug type, and (3) flat or curved swinging-door type (see Fig. 5). The clam-shell type offers advantages in that control forces are lower than the other types. Moving parts of this nozzle are outside of the exhaust pipe, offering the possibility of effectively cooling critical items such as the shells and bearings. The clam-shell type, in general, also allows a larger area change than with the plug type. A disadvantage of the clam-shell nozzle is the difficulty in sealing against gas leakage between the moving shells and exhaust pipe. The swinging-door type nozzle has the virtue of being relatively simple and shows good performance over a wide range of pressure ratios and area changes.

(C) Jet-Nozzle Performance

The general expression for the flow through any nozzle is the product of flow coefficient times the theoretical flow. The flow coefficient is usually determined experimentally, while the theoretical flow is the calculated flow of the theoretically perfect nozzle under the pressure and temperature conditions at the nozzle

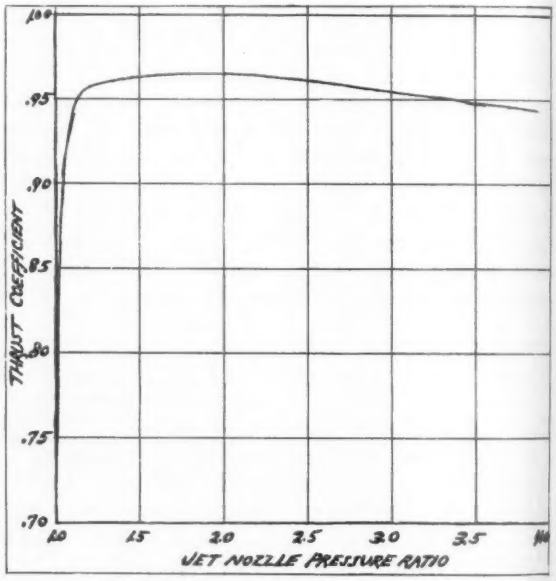

FIG. 6. General performance of fixed-area nozzle—conical type.

inlet and discharge. Flow coefficient can also be expressed as the product of area coefficient times velocity coefficient, where area coefficient is the ratio of the area of the gas stream at the vena contract to the nozzle discharge area. The velocity coefficient is the ratio of the actual jet velocity produced by the nozzle to the theoretical velocity and thus is a measure of the nozzle energy loss.

Jet thrust can be expressed in general terms as

$$\text{Jet Thrust} = \frac{\text{Measured Flow} \times \text{Actual Jet Velocity}}{g} = \frac{\text{Measured Flow} \times \text{Theoretical Vel.} \times \text{Vel. Coefficient}}{g}$$

As the thrust is directly proportional to the velocity coefficient, this coefficient is generally called a nozzle or thrust efficiency. The flow coefficient is important only in determining the size of nozzle or nozzle opening

to pass the required flow. For example, at jet-nozzle pressure ratios below critical and for equal flows, a square-edged orifice plate with a flow coefficient of 0.60 could give a higher thrust than a well-rounded nozzle with a flow coefficient of 0.98. This is because the side-wall friction is not present in square-edged orifice to decrease the velocity, thus resulting in a higher velocity coefficient or thrust efficiency for the orifice.

As the jet-nozzle pressure ratio is increased from a low to a high value, the highest thrust coefficients could be obtained by using successively a flat plate orifice, a conical nozzle, a parallel throat nozzle, or a converging-diverging nozzle. In jet-nozzle design a general shape is usually selected which has a high velocity coefficient in the region it will operate in on the turbojet. The range of operation of our present turbojet units has dictated the use of the general conical shape.

A typical thrust efficiency curve for the fixed-area conical nozzle generally in use today is shown on Fig. 6. The variable area nozzles (because of consideration of leakage around moving parts, added viscosity, and form effects) exhibit slightly lower thrust efficiencies than the fixed conical nozzles. The maximum thrust efficiency of the central plug, clam-shell, and swinging-door type nozzles is about 1 to 2 per cent lower than the fixed nozzle. This slight loss in efficiency can probably be reduced by refinement in the design of these nozzles.

Aircraft Flight Testing in Miniature

(*Continued from page 32*)

flight operations are considered as a function beyond usual university liability, and the student is therefore required to sign a waiver of such liability in case of accident.

Since the material covered by the present course is ample for the time involved, the plans for the future improvements of the facility are visualized primarily in terms of theses projects. Currently, an accurate propeller-pitch indicator for studying propeller effects quantitatively is being designed. Installation of a sensitive accelerometer will allow the study of stick-force gradients in steady turns. Other proposed projects are investigation of effects of cylinder-head temperature on power and performance, correlation with wind-tunnel tests, determination of gain in $V_{max.}$ due to cleaning and waxing of aircraft, and tuft and rake studies for approximate drag coefficient determination.

It is probably an understatement to remark that the student reaction to the course is positive. They participate actively and are willing to undergo many inconveniences to make up for lost time due to weather and unexpected malfunctioning of instruments. It is believed that they absorb a great deal of the true spirit of an up-to-date flight test section (including weather and malfunctioning frustration) in connection with this small facility. In conclusion, it can therefore be stated that the development of a flight-testing course, with a total capital investment in the airplane and the instrumentation of approximately $7,500, is feasible and worth while.

Reprints of "The Earth's Atmosphere" Now Available

In view of the unprecedented demand for the article "The Earth's Atmosphere" by Howard E. Roberts (*Aeronautical Engineering Review*, Volume 8, Number 10, October, 1949), we have reprinted the article and are making it available, together with the chart on the Characteristics of the Earth's Atmosphere, to all who are interested in obtaining copies.

Reprints of the article, including the chart, may be obtained for 65 cents (members) or $1.00 (non-members) by writing to:

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A Report on the General Assembly of the International Union of Theoretical and Applied Mechanics

By N. J. Hoff*

[*Editor's Note:* Dr. Hoff graciously agreed to serve as official representative of the Institute to this international assembly. We acknowledge with gratitude his services in this connection and the following interesting report he has submitted for our readers.]

THE GENERAL ASSEMBLY of the International Union of Theoretical and Applied Mechanics met at Verbania-Pallanza, in Italy, from June 23 to June 27, 1950. The objects of the Union are the establishment of a link between persons and national organizations engaged in scientific work in mechanics; the organization of international conferences; and, in general, the promotion of development in the science of mechanics. In the United States, the adhering organization to the Union is the U.S. National Committee on Theoretical and Applied Mechanics, which was formed by the following societies: American Society of Mechanical Engineers, American Society of Civil Engineers, Institute of the Aeronautical Sciences, American Institute of Chemical Engineers, American Mathematical Society, Fluid Dynamics Branch of the American Physical Society, and Society for Experimental Stress Analysis.

The main purpose of the meeting in Italy was the discussion of a proposal by the British group to amend the by-laws of the International Union. The present by-laws differ considerably from those of all the other scientific unions. They provide for two classes of membership: one consists of the representatives of the various national organizations, and the other is comprised of persons elected by the Union for a term of years because of their past contributions to mechanics and their work in the International Committee for the Congresses of Applied Mechanics. This unusual feature of the by-laws is a consequence of the desire of the Union to take over gradually the work of the International Committee for the Congresses of Applied Mechanics, which has been singularly successful in holding congresses since 1924. The stature of the individual members can be judged from the list of those who reside in the United States. They are Hugh L. Dryden, J. C. Hunsaker, Th. von Kármán, R. von Mises, and S. P. Timoshenko.

The adhering organization in Great Britain is The Royal Society, an independent nonpolitical scientific organization of high standards and great traditions, which is supported by the government. The Royal Society, as the official adhering organization to all the scientific unions, desired that the by-laws of the various unions be made uniform. This would be possible through abolishing the individual membership in the International Union of Theoretical and Applied Mechanics. The representatives of the other nations were almost unanimously opposed to this plan. They felt that one of the most important objectives of the Union was the organization of the congresses and that this could be accomplished by the Union only if it gradually absorbed the members of the International Committee for the Congresses of Applied Mechanics. Moreover, it appeared that the only manner in which all-out support of the Union by the distinguished members of the International Committee could be obtained was the individual membership provided for in the original by-laws.

The stalemate was broken when Dr. Dryden offered the following resolution:

"In confirmation of the views already expressed at the General Assembly of September, 1948, when the present statutes were framed:

"(1) The General Assembly expects that, in those countries where more than one national organization is active in theoretical and applied mechanics, a national coordinating committee will be formed. In general, it is expected to recognize only one adhering body in each country.

"(2) The General Assembly believes that a gradual transition should be made in its composition, so that ultimately it will consist mainly of representatives of organizations adhering to the Union, with the category of elected members reserved for exceptional and unusual cases. To this end it gives notice of its intention to reduce the number of elected members when the terms of the present elected members expire in 1952."

When this resolution was adopted, Sir David Brunt, the spokesman of the British delegation, withdrew his motion.

It was encouraging to see that in this case, as well as in all the other controversial issues discussed, a group of people comprising eight different nationalities was always capable of arriving at unanimous agreements and, although sometimes after heated arguments, at solutions agreeable to all.

The business meeting of the Union was preceded by 2 days of informal scientific discussion. On June 23, I presented a paper entitled "Report on the Investigation of the Dynamics of the Buckling Process." This was followed by F. H. van den Dungen's lecture, "Une erreur classique dans le problème des charges mobiles," and by F. Merlino's presentation, "Instruments de mesure des déformations très petites." On June 24,

* Head, Department of Aeronautical Engineering and Applied Mechanics, Polytechnic Institute of Brooklyn.

M. G. Salvadori spoke on "The Numerical Evaluation of Characteristic Values by Finite Differences and Extrapolations." F. Levi presented the paper "Fondements théoriques d'une étude directe des états de contrainte provoqués par une déformation non compatible," and R. Seeger spoke on "Some Remarks on Aerophysical Research." In the afternoon session of the same day, J. Ackeret reported "On Recent Investigations." This was followed by "On Correlation Problems in a Model of Turbulence" by J. M. Burgers and "Recent Work on Unsteady Supersonic Motion" by G. Temple.

The meeting was opened by Prof. G. Colonnetti, the Italian member of the International Union, who organized the meeting in Pallanza. He welcomed the delegates to Italy in the name of the National Research Council, of which he is president. The meeting was presided over by Prof. J. Pérès. Reports of the secretary, treasurer, and chairmen of the committees were accepted, and considerable discussion took place after the scientific presentations.

The meeting was attended by Sir David Brunt (Imperial College, London), Sir Charles Darwin (Cambridge), Prof. A. A. Hall (Imperial College, London) and Prof. G. Temple (Kings College, London) from Great Britain; Prof. C. B. Biezeno (Polytechnic Institute of Delft), Prof. J. M. Burgers (Polytechnic Institute of Delft), and Mr. C. Koning (National Aeronautical Laboratories, Amsterdam) from Holland; Prof. F. K. G. Odqvist (Royal Polytechnic Institute, Stockholm) and Prof. W. Weibull (Royal Polytechnic Institute, Stockholm) from Sweden; Prof. J. Ackeret (Federal Polytechnic Institute, Zurich) and Prof. H. Favre (Federal Polytechnic Institute, Zurich) from Switzerland; Prof. J. Pérès (University of Paris) from France; Prof. J. Solberg (University of Oslo) from Norway; Prof. A. Coppens (University of Louvain) and Prof. F. H. van den Dungen (University of Brussels) from Belgium; Prof. G. Colonnetti (Polytechnic Institute of Turin) and Gen. A. Crocco (Rome) from Italy; and Dr. Hugh L. Dryden (Director of Research, National Advisory Committee for Aeronautics), Prof. N. J. Hoff (Head of Department of Aeronautical Engineering and Applied Mechanics, Polytechnic Institute of Brooklyn), Dr. Th. von Kármán (Chairman, Scientific Advisory Board, United States Air Force), Prof. M. G. Salvadori (Department of Civil Engineering, Columbia University), Dr. R. J. Seeger, Chief of Aero-Ballistics Research Department, Naval Ordnance Laboratories, Silver Spring, Md., and Prof. S. P. Timoshenko (Stanford University), from the United States.

Attending as observers were Dr. S. C. Lowell, of the Office of Naval Research, American Embassy, London, England, and Capt. R. Crawford, U.S.A.F., of the American Embassy, Paris, France.

Social meetings and excursions to view the natural and architectural beauties of the North Italian landscape were arranged by Mrs. Colonnetti, who, with the aid of her two daughters and of Miss Rosanna Coda and Mr. P. L. Romita, contributed a great deal to the success of the meeting.

I.A.S. National Meeting Schedule

Wright Brothers Lecture—U. S. Chamber of Commerce Auditorium, Washington, D.C.—December 16

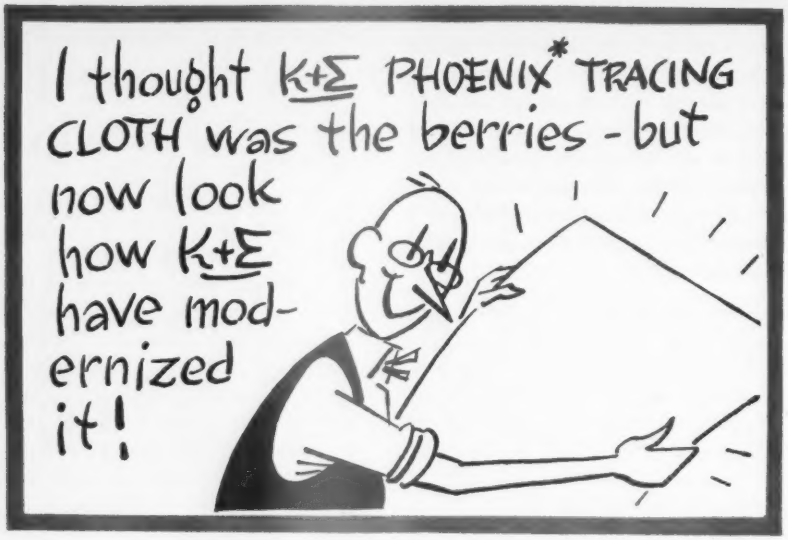
Nineteenth Annual Meeting—Hotel Astor, New York, January 29–31, February 1, 1951

Members or organizations wishing to submit papers for presentation at National Meetings should send outlines or summaries to the Committee no later than 5 months prior to the meeting.

All papers submitted will be considered for publication in the *Journal of the Aeronautical Sciences* or the *Aeronautical Engineering Review*.

All correspondence should be addressed to:

The Meetings Committee, Institute of the Aeronautical Sciences, 2 East 64th Street, New York 21, N.Y.



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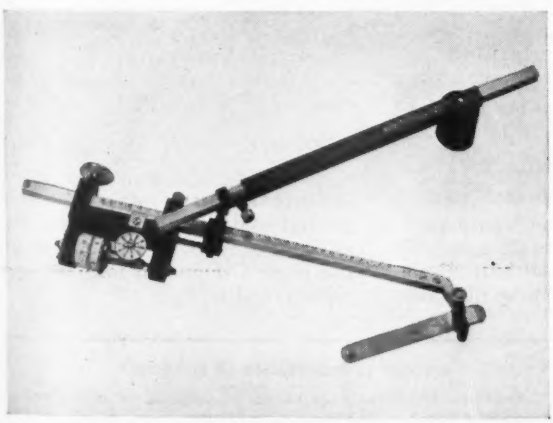

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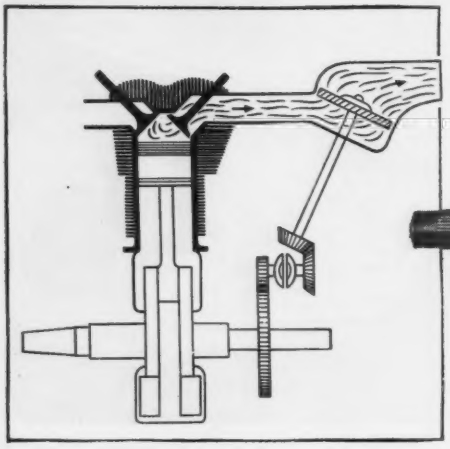

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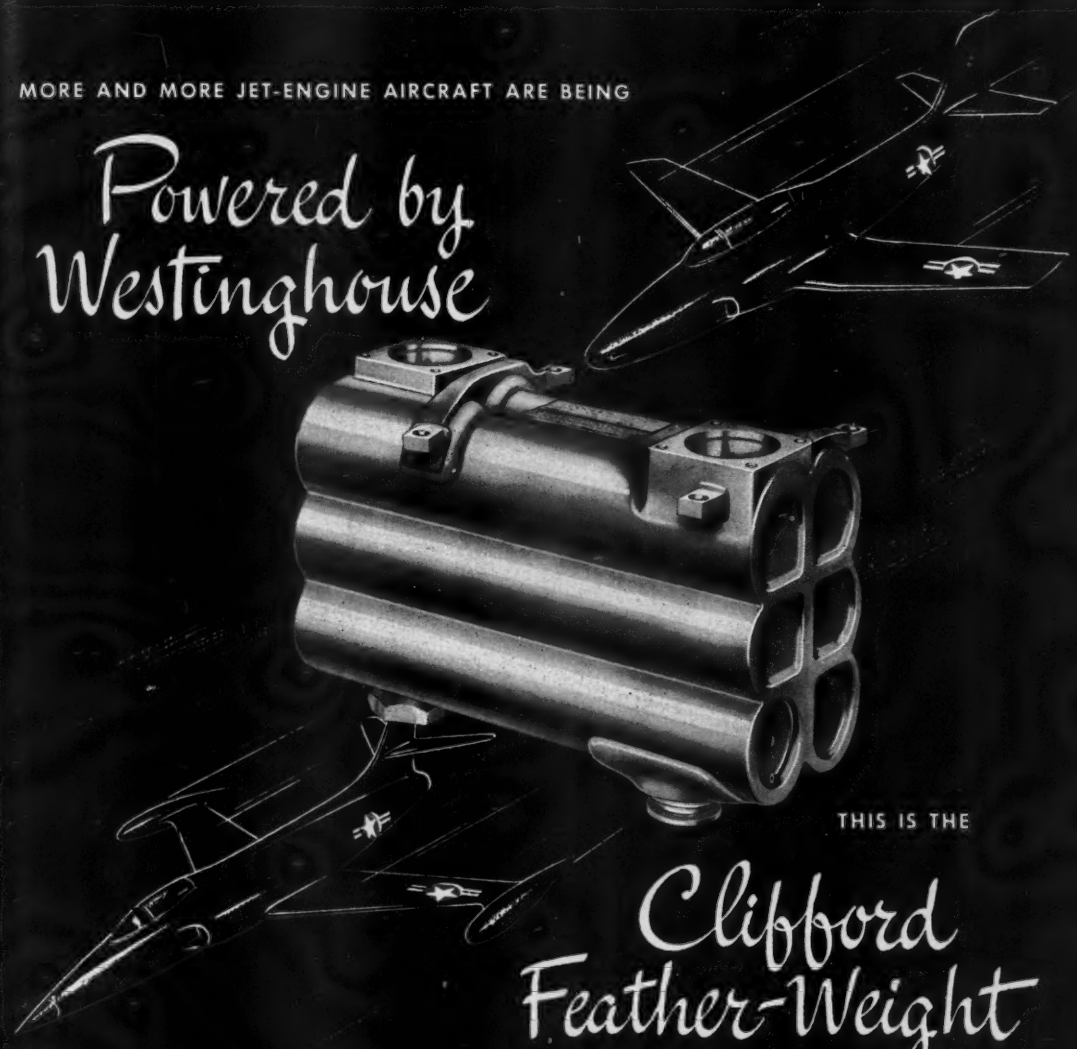

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Aeronautical Reviews

A Guide to the Current Literature of Aeronautical Research and Engineering

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Aerodynamics (2)

Jet Flow and Its Effects on Aircraft. H. B. Squire. *Aircraft Engineering*, Vol. 22, No. 253, March, 1950, pp. 62–67, illus. 4 references.

Data on round jets in still air and in a general stream and on the temperature distribution for heated jets are analyzed to determine the spread of the jet and the decay of the axial velocity distribution. In the model testing of jets and jet aircraft, jet momentum is the most important quality in the simulation of a hot jet. Illustrations of the effect of jets on neighboring surfaces include the Coanda effect. Analysis is made of the effect of jets on aircraft stability.

BOUNDARY LAYER

Further Experimental Studies of Area Suction for the Control of the Lamlnar Boundary Layer on a Porous Bronze NACA 64A010 Airfoil. Albert L. Braslow and Fioravante Visconti. *U.S., N.A.C.A., Technical Note No. 2112*, May, 1950. 10 pp., illus. 4 references.

Further Wind Tunnel Tests on a 30 Per Cent. Symmetrical Suction Aerofoil with a Movable Flap. N. Gregory and W. S. Walker. *Gt. Brit., Aeronautical Research Council, Reports and Memoranda No. 2287*, 1950 (July, 1946). 23 pp., illus. 6 references. British Information Services, New York. $1.15.

A given lift coefficient can be obtained with a Griffin suction airfoil at a much smaller angle of incidence when there is a positive flap setting than with zero flap angle, and less suction is required to prevent separation. The suction quantity is high at a Reynolds Number of 0.96×10^6 but shows a continuous decrease with increasing Reynolds Number. With no suction and with laminar flow to the slot, the drag coefficient has a low value for the thickness of the airfoil.

Instrument for Measuring the Wall Shearing Stress of Turbulent Boundary Layers. H. Ludwieg. *U.S., N.A.C.A., Technical Memorandum No. 1284*, May, 1950. 22 pp., illus. 9 references.

Readers' Forum: Comments on "Heat Transfer in Laminar Compressible Boundary Layer . . ." P. Grootenhuis. *Journal of the Aeronautical Sciences*, Vol. 17, No. 9, September, 1950, p. 595.

Boundary-Layer Transition on a Cooled 20° Cone at Mach Numbers of 1.5 and 2.0. Richard Scherrer. *U.S., N.A.C.A., Technical Note No. 2131*, July, 1950. 13 pp., illus. 5 references.

Characteristics of the Turbulent Boundary Layer on a Flat Plate in Compressible Flow from Measurements of Friction in Pipes. Hans Ulrich Eckert. *Journal of the Aeronautcial Sciences*, Vol. 17, No. 9, September, 1950, pp. 573–584, illus. 16 references.

Turbulent Boundary-Layer Characteristics at Supersonic Speeds—Theory and Experiment. Robert E. Wilson. *Journal of the Aeronautical Sciences*, Vol. 17, No. 9, September, 1950, pp. 585–594, illus. 14 references.

FLUID MECHANICS & AERODYNAMIC THEORY

Solution of a Non-Linear Equation for Transonic Flow with Rotational Symmetry. E. W. Graham. *Douglas Aircraft Company, Inc., Report No. SM-13677*, December 8, 1949. 24 pp., illus. 1 reference.

A nonlinear transonic equation for flow with rotational symmetry is solved by series expansion in the independent variables when the uniform initial flow is at sonic velocity and the flow contains no subsonic regions. The pressure distribution for a body that extends as a circular cylinder to infinity in the upstream direction with its axis parallel to the flow direction and whose rear portion has decreasing cross-sectional area in the downstream direction shows fairly good agreement with the theoretical values for two-dimensional bodies of the same profile. This agreement is shown to be true in general if the pressure coefficient is everywhere small compared to the ratio of longitudinal to lateral curvature.

Exact Solutions of Equations of Gas Dynamics. I. A. Kiebel. (*Prikladnaia Matematika i Mekhanika, U.S.S.R.*, Vol. 11, 1947, pp. 193–198.) *U.S., N.A.C.A., Technical Memorandum No. 1260*, June, 1950. 12 pp., illus. 1 reference.

Results of Recent Hypersonic and Unsteady Flow Research at the Langley Aeronautical Laboratory. John Becker. *Journal of Applied Physics*, Vol. 21, No. 7, July, 1950, pp. 619–628, illus. 14 references.

A brief review of the development of the Langley 11-in. hypersonic wind tunnel and of air condensation experiments conducted in the tunnel nozzle; nitrogen afterglow technique for flow visualization at low pressures; boundary-layer effects at hypersonic speeds; shock-boundary-layer interaction; pressure variations in shock tubes; and the unsteady flow problem of supersonic diffusers.

Elliptic Integral Representation of Axially Symmetric Flows. M. A. Sadowsky and E. Sternberg. *Quarterly of Applied Mathematics*, Vol. 8, No. 2, July, 1950, pp. 113–126, illus. 12 references.

The potentials, stream functions, and velocity components for basic axially symmetric distributions of sources or vorticity over the circumference ot the interior of a circle are established in terms of elliptic integrals of the first and second kind. This approach yields an analytically more transparent description than that employing discontinuous integrals of Bessel functions. It also gives further insight into the cyclic character of Stokes' stream function or the velocity potential. The use of functions that have been tabulated exhaustively facilitates physical interpretation of the results and renders possible complete determination of the corresponding streamline patterns. By superposition of the basic axially symmetric flows and appropriately chosen uniform streams, one may obtain technically significant flows around solid and annular shaped bodies and half-bodies of revolution.

On the Thickness of a Steady Shock Wave. R. von Mises. *Journal of the Aeronautical Sciences*, Vol. 17, No. 9, September, 1950, pp. 551–554, 594, illus. 4 references.

Readers' Forum: Application of Biezeno-Koch Method to Compressible Fluid Flow Problems. Chi-Teh Wang and Pei-Chi Chou. *Journal of the Aeronautical Sciences*, Vol. 17, No. 9, September, 1950, pp. 599, 600, illus. 10 references.

Critical Conditions for Compressible Flow. W. G. Bickley. *Gt. Brit., Aeronautical Research Council, Reports and Memoranda No. 2330*, 1950 (May 27, 1946). 9 pp., illus. 8 references. British Information Services, New York. $0.50.

A summary of mathematical studies that suggest that breakdown of continuous flow over an airfoil need not occur at the critical Mach Number and which support a physical intuition that critical conditions occur when the component of the velocity in the direction of the pressure gradient is sonic.

A New Approach to Problems in Two Dimensional Flow. Monroe H. Martin. *Quarterly of Applied Mathematics*, Vol. 8, No. 2, July, 1950, pp. 137–150, illus. 13 references.

The equations of motion and continuity of steady two-dimensional fluid flow are integrated by using the stream function and the pressure as independent variables. The fluid velocity then becomes an arbitrary function whose specification characterizes the system.

Studies of Two-Dimensional Transonic Flows of a Compressible Fluid. II. S. Tomotika and K. Tamada. *Quarterly of Applied Mathematics*, Vol. 8, No. 2, July, 1950, pp. 127–136, illus. 2 references.

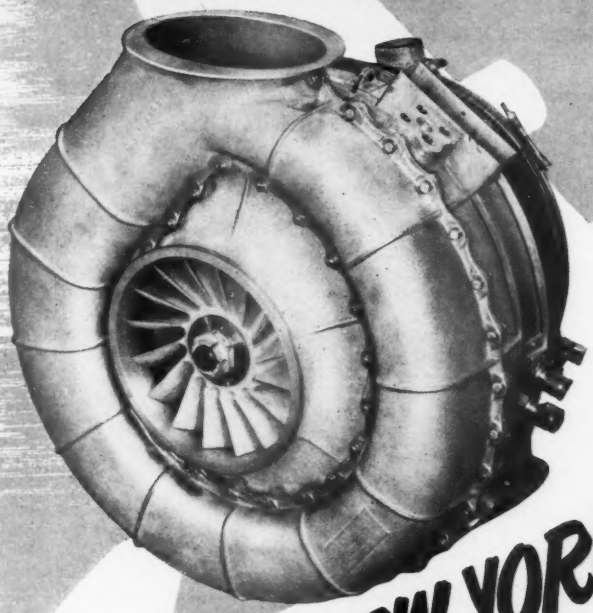
A development based on the fundamental differential equation governing the flow of a hypothetical gas that becomes linear in the hodograph plane. By suitable linear combinations of an appropriate exact solution of this linear equation, various flow patterns of practical interest are obtained.

The Hot-Wire Anemometer in Supersonic Flow. Leslie S. G. Kovasznay. *Journal of the Aeronautical Sciences*, Vol. 17, No. 9, September, 1950, pp. 565–572, 584, illus. 7 references.

Readers' Forum: Comment on "Heat Source in a Uniform Flow." B. L. Hicks, W. H. Hebrank, and S. Kravitz. *Journal of the Aeronautical Sciences*, Vol. 17, No. 9, September, 1950, pp 595, 596, illus. 4 references.

The Determination of Pressure on Curved Bodies Behind Shocks. T. Y. Thomas. *Communications on Pure and Applied Mathematics*, Vol. 3, No. 2, June, 1950, pp. 103–132, illus. 7 references.

By assuming the inclination of the boundary of an obstacle in steady, plane, supersonic flow to be a monotonically decreasing or increasing function of the arc length of the attached shock line at the vertex of the body and by assuming the entropy to be zero at the boundary, the pressure function is represented by a power series in the entropy with coefficients depending on the inclination of the stream lines. By terminating the series after the sum of its first n terms, a differential equation is obtained which is of finite order for the nth approximation of pressure on the boundary.



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Explicit equations for the first, second, and third approximations of the pressure are given in a form suitable for calculation.

An Analysis of Base Pressure at Supersonic Velocities and Comparison with Experiment. Dean R. Chapman. *U.S., N.A.C.A., Technical Note No. 2137*, July, 1950. 69 pp., illus. 11 references.

Wall Effects in Cavity Flow. I. G. Birkhoff, M. Plesset, and N. Simmons. *Quarterly of Applied Mathematics*, Vol. 8, No. 2, July, 1950, pp. 151–168, illus. 5 references.

Free Boundaries and Jets in the Theory of Cavitation. David Gilbarg and James Serrin. *Journal of Mathematics and Physics*, Vol. 29, No. 1, April, 1950, pp. 1–12, illus. 11 references.

Drag and Pressure Measurements with Plaster Spheres in Wind Tunnel 3 and 4 of the National Aeronautical Research Institute. S. I. Wiselius. *Netherlands, National Luchtvaartlaboratorium, Report No. A.950 (Verslagen en Verhandelingen*, Vol. 13, pp. A1–A8), 1947. 8 pp., illus. 8 references. (In English.)

INTERNAL FLOW

On the Linearized Theory of Supersonic Flows Through Axially Symmetrical Ducts. I. Kolodner. *Communications on Pure and Applied Mathematics*, Vol. 3, No. 2, June, 1950, pp. 133–152, illus. 8 references.

The behavior of an inviscid, compressible fluid entering an axially symmetrical duct of slowly varying cross section, with a constant supersonic velocity in the direction of the axis of the duct. To formulate the problem analytically, cylindrical coordinates are used. The nature of the flow is shown to depend essentially on a duct function. This dependence is illustrated and discussed in detail.

Analytical and Experimental Investigation of Adiabatic Turbulent Flow in Smooth Tubes. Robert G. Deissler. *U.S., N.A.C.A., Technical Note No. 2138*, July, 1950. 41 pp., illus. 6 references.

Investigation of Turbulent Flow in a Two-Dimensional Channel. John Laufer. *U.S., N.A.C.A., Technical Note No. 2123*, July, 1950. 67 pp., illus. 20 references.

Readers' Forum: Potential Flow Around a Rotating, Advancing Cylindrical Blade. L. E. Fogarty and W. R. Sears. *Journal of the Aeronautical Sciences*, Vol. 17, No. 9, September, 1950, p. 599. 1 reference.

Method of Analysis for Compressible Flow Through Mixed-Flow Centrifugal Impellers of Arbitrary Design. Joseph T. Hamrick, Ambrose Ginsburg, and Walter M. Osborn. *U.S., N.A.C.A., Technical Note No. 2165*, August, 1950. 29 pp., illus. 3 references.

A Numerical Procedure for Designing Cascade Blades with Prescribed Velocity Distributions in Incompressible Potential Flow. Arthur G. Hansen and Peggy L. Yohner. *U.S., N.A.C.A., Technical Note No. 2101*, June, 1950. 51 pp., illus. 6 references.

Spectrums and Diffusion in a Round Turbulent Jet. Stanley Corssin and Mahinder S. Uberoi. *U.S., N.A.C.A., Technical Note No. 2124*, July, 1950. 80 pp., illus. 28 references.

NATURAL FLIGHT

Bird Flight. C. H. Latimer-Needham. *The Aeroplane*, Vol. 78, No. 2033, May 26, 1950, pp. 618, 619, illus. Notes on the motions of birds' wings.

PARASITIC COMPONENTS & INTERFERENCE

Sidewash and Stability; A Study of Wings/Fuselage Interference Effects. H. K. Millicer. *Flight*, Vol. 58, No. 2107, July 27, 1950, pp. 128–130, illus.

The Installation of an Engine Nacelle on a Wing. I—Model Tests on a Symmetrical Wing. R. Smelt and A. G. Smith. **II—Underslung Nacelles on Cambered Wings.** R. Smelt and F. Smith. **III—Pitching-Moment Changes Due to Nacelles.** F. Smith and R. Smelt. **IV—Effects of Fuselage and Tractor Airscrew.** R. Smelt and B. Davison. *Gt. Brit., Aeronautical Research Council, Reports and Memoranda No. 2406*, 1950 (November, 1939). 83 pp., illus. 14 references. British Information Services, New York. $3.40.

PERFORMANCE

Performance Estimation of Civil Jet Aircraft. I, II, III. Alun D. Edwards. *Aircraft Engineering*, Vol. 22, Nos. 253, 254, 255, March, April, May, 1950; pp. 70–75; pp. 94–99; pp. 143–145; illus.

Formulas for estimating the performance of jet aircraft during take-off on full power, the initial climb to cruising altitude, during the cruise, and during landing. Allowance is made for the effect of wind, rocket-assisted take-off, engine failure, the effect of flaps, the work done by wheel brakes, and the variation in thrust which is required during flight to accommodate for horizontal distance traveled and fuel consumed.

The Possibility of the Determination of Rate of Climb from Acceleration Measurements in Level Flight. E. C. Pike. *The Aeronautical Quarterly*, Vol. 2, Part 1, May, 1950, pp. 15–22, illus. 3 references.

Since the rate of climb of an aircraft is proportional to the product of its velocity and acceleration in level flight, measurements made of these two quantities can be used to determine the rate of climb at any altitude. The "nondimensional" curves of aircraft performance can be plotted directly from data obtained in a series of test runs at different altitudes and at different engine speeds. The instrumentation of the aircraft would have to include an automatic observer incorporating a longitudinal accelerometer sensitive to 0.001*g*.

Notes on the Dog Fight. S. B. Gates. *Gt. Brit., Aeronautical Research Council, Reports and Memoranda No. 2381*, 1950 (June, 1940). 8 pp., illus. 2 references. British Information Services, New York. $0.40.

Two aspects of the dogfight are analyzed: the breakaway from line combat at high speed and the concentric attack. The analysis of concentric attack has led to a compact diagram for making a rough estimate of the turning performance when the straight-flight performance is known.

STABILITY & CONTROL

Flight Measurements of the Directional Stability and Trim on the Mustang III with Various Modifications to Improve the Directional Stability. H. V. Becker and D. J. Lyons. *Gt. Brit., Aeronautical Research Council, Reports and Memoranda No. 2317*, 1950 (January, 1946). 15 pp., illus. 8 references. British Information Services, New York. $0.75.

Method of Calculating the Lateral Motions of Aircraft Based on the Laplace Transform. Harry E. Murray and Frederick C. Grant. *U.S., N.A.C.A., Technical Note No. 2129*, July, 1950. 54 pp., illus. 12 references.

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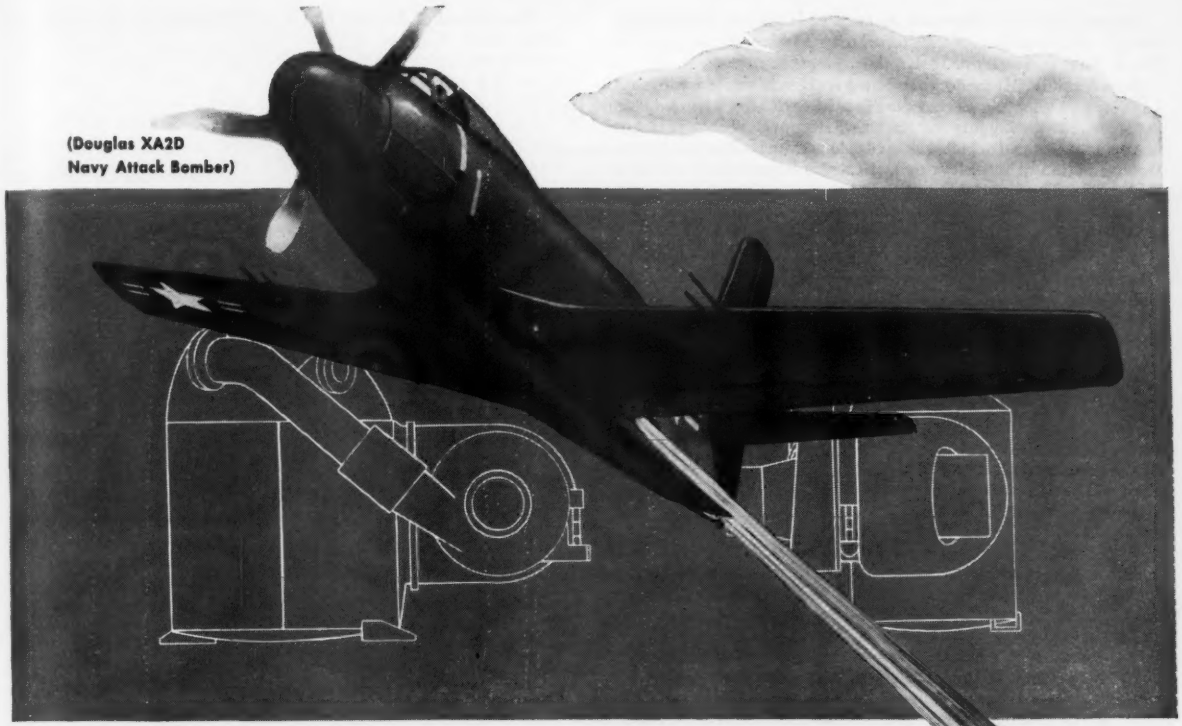

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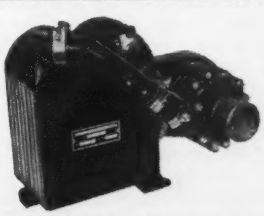

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Lateral Control of Personal Aircraft at High Lift Coefficients. Francis M. Rogallo. *Aeronautical Engineering Review*, Vol. 9, No. 8, August, 1950, pp. 18–22, illus. 24 references.

Benaderende Methode voor het Berekenen van de voor het Landen een Vliegtuig Vereischte Hoogteroeruitslagen en van de meest Voorlijke Ligging van het Zwaartepunt, Welke met het oog op het Landen Toelaatbaar Is (An Approximate Method for the Determination of the Elevator Deflections Required for Landing an Aeroplane and of the Extreme Forward Position of the Center of Gravity, Which Is Admissible in View of the Landing Characteristics). A. J. Marx. *Netherlands, Nationaal Luchtvaartlaboratorium, Report No. V.1286 (Verslagen en Verhandelingen*, Vol. 13, pp. V19–V51), 1947. 33 pp., illus. (In Dutch; English Summary.)

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WINGS & AIRFOILS

The Linearized Theory of Conical Fields in Supersonic Flow, with Applications to Plane Aerofoils. S. Goldstein and G. N. Ward. *The Aeronautical Quarterly*, Vol. 2, Part 1, May, 1950, pp. 39–84, illus. 27 references.

The equations of linearized supersonic conical fields and their general solution are set out both for the region inside and for the region outside the Mach cone of the origin in the conical field. The results are applied to the six cases of flow past plane triangular airfoils with straight edges downstream of the vertex, to flow past those airfoils of more extended shape and finite span for which solution may be obtained by combining a finite number of conical fields, and to the problem of plane triangular vanes in semi-infinite jets. The velocity fields are determined in detail in order to exhibit the mathematical methods used and the physical considerations that enter in determining the mathematical solution.

The Development of Cambered Airfoil Sections Having Favorable Lift Characteristics at Supercritical Mach Numbers. Donald J. Graham. *U.S., N.A.C.A., Report No. 947*, 1949. 22 pp., illus. 5 references. U.S. Govt. Printing Office, Washington. $0.20.

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Estimation of the Damping in Roll of Supersonic-Leading-Edge Wing-Body Combinations. Warren A. Tucker and Robert O. Piland. *U.S., N.A.C.A., Technical Note No. 2151*, July, 1950. 20 pp., illus. 6 references.

A linear-theory method for the estimation of the damping in roll of supersonic-leading-edge wings mounted on cylindrical bodies. The method is applied to the calculation of the damping in roll of rectangular- and triangular-wing configurations. Limitations are discussed.

Lift-Cancellation Technique in Linearized Supersonic-Wing Theory. Harold Mirels. *U.S., N.A.C.A., Technical Note No. 2145*, August, 1950. 43 pp., illus. 15 references.

Two-Dimensional Unsteady Lift Problems in Supersonic Flight. Max A. Heaslet and Harvard Lomax. *U.S., N.A.C.A., Report No. 945*, 1949. 9 pp., illus. 7 references. U.S. Govt. Printing Office, Washington. $0.15.

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On the Relation Between Wave Drag and Entropy Increase. H. W. Liepmann. *Douglas Aircraft Company, Inc., Report No. SM-13718*, March 16, 1950. 37 pp., illus. 11 references.

The relations between the wave drag of a body moving with supersonic speed and the increase of entropy of the air that passes through the shock wave system of the moving body are applied to thin two-dimensional flat-plate airfoils and thin two-dimensional biconvex airfoils. These entropy-drag relations are applicable to transonic flow. Heat conduction and viscosity within a shock wave constitute the mechanism that accounts for the increase in entropy. A short proof justifies the assumption of irrotational flow in the supersonic thin-airfoil theory.

The Effects of Amount and Type of Camber on the Variation with Mach Number of the Aerodynamic Characteristics of a 10-Percent-Thick NACA 64A-Series Airfoil Section. James L. Summers and Stuart L. Treon. *U.S., N.A.C.A., Technical Note No. 2096*, May, 1950. 66 pp., illus. 4 references.

Theoretical Lift and Damping in Roll of Thin Wings with Arbitrary Sweep and Taper at Supersonic Speeds: Supersonic Leading and Trailing Edges. Sidney M. Harmon and Isabella Jeffreys. *U.S., N.A.C.A., Technical Note No. 2114*, May, 1950. 49 pp., illus. 16 references.

Theory of an Oscillating Supersonic Aerofoil. Geoffrey L. Sewell. *The Aeronautical Quarterly*, Vol. 2, Part I, May, 1950, pp. 34–38, illus. 2 references.

In the previous linearized theories of steady supersonic flow past a slender oscillating airfoil, the shock line at the nose has been assumed to be a straight, stationary one, so that no vorticity is produced on passing through it. In the present treatment, the possibility that the shock may be both curved and moving is taken into account, but the result is exactly the same as that obtained by the previous treatments (e.g., Temple and Jahn).

Calculation of Transonic Flows Past Thin Airfoils by an Integral Method. William Perl. *U.S., N.A.C.A., Technical Note No. 2130*, July, 1950. 96 pp., illus. 53 references.

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Theoretical Antisymmetric Span Loading for Wings of Arbitrary Plan Form at Subsonic Speeds. John DeYoung. *U.S., N.A.C.A., Technical Note No. 2140*, July, 1950. 95 pp , illus. 9 references.

Low-Speed Model Tests on a "U" Wing. J. Trouncer and G. F. Moss. *Gt. Brit., Aeronautical Research Council, Reports and Memoranda No. 2295*, 1950 (July, 1945). 16 pp., illus. 2 references. British Information Services, New York. $0.75.

The effects of the end fins and the split flaps on a model "U"-wing tailless glider were in good agreement with those obtained with a "V"-wing plan form. The addition of the fuselage, however, caused a severe breakaway to occur in the wing-fuselage junction. Center section slats remove this breakaway, but the resulting pitching-moment curve is unstable above a lift coefficient of 0.7 or thereabouts. The maximum trimmed lift on the wing alone is 1.12 with the stability neutral or slightly unstable above a lift coefficient of 0.8.

A Note on Subsonic Aerofoil Theory. John W. Miles. *The Aeronautical Quarterly*, Vol. 2, Part I, May, 1950, pp. 23–33, illus. 20 references.

A linearized theory for the subsonic, lifting surface problem is formulated in terms of Fourier integral solutions to Laplace's equation. The symmetric and antisymmetric problems of the first kind are solved explicitly, while the problems of the second kind depend on the solution of dual integral equations. The antisymmetric problem of the second kind is cast in a variational form, from which certain well-known theorems may be deduced.

Flight Tests on "King Cobra" FZ.440 to Investigate the Practical Requirements for the Achievement of Low Profile Drag Coefficients on a "Low Drag" Aerofoil. F. Smith and D. J. Higton. *Gt. Brit., Aeronautical Research Council, Reports and Memoranda No. 2375*, 1950 (August, 1945). 20 pp., illus. 3 references. British Information Services, New York. $1.00.

Measurements of profile drag were made on the wing of the King Cobra aircraft, which has a low-drag profile of N.A.C.A. design. The profile drag was high with the original surface finish, and, although it was improved when the surface was polished, the profile drag was still much too high for a low-drag airfoil. By reduction of the surface waviness to ±0.001 in., low drag coefficients of the order of 0.0028 were obtained. Also described are the technique used to reduce the waviness and the effect of flies, dust, water, high Mach Number, and normal acceleration upon the low-drag characteristics of the wing.

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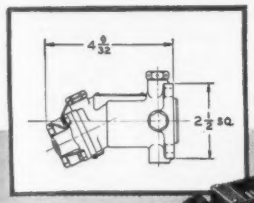

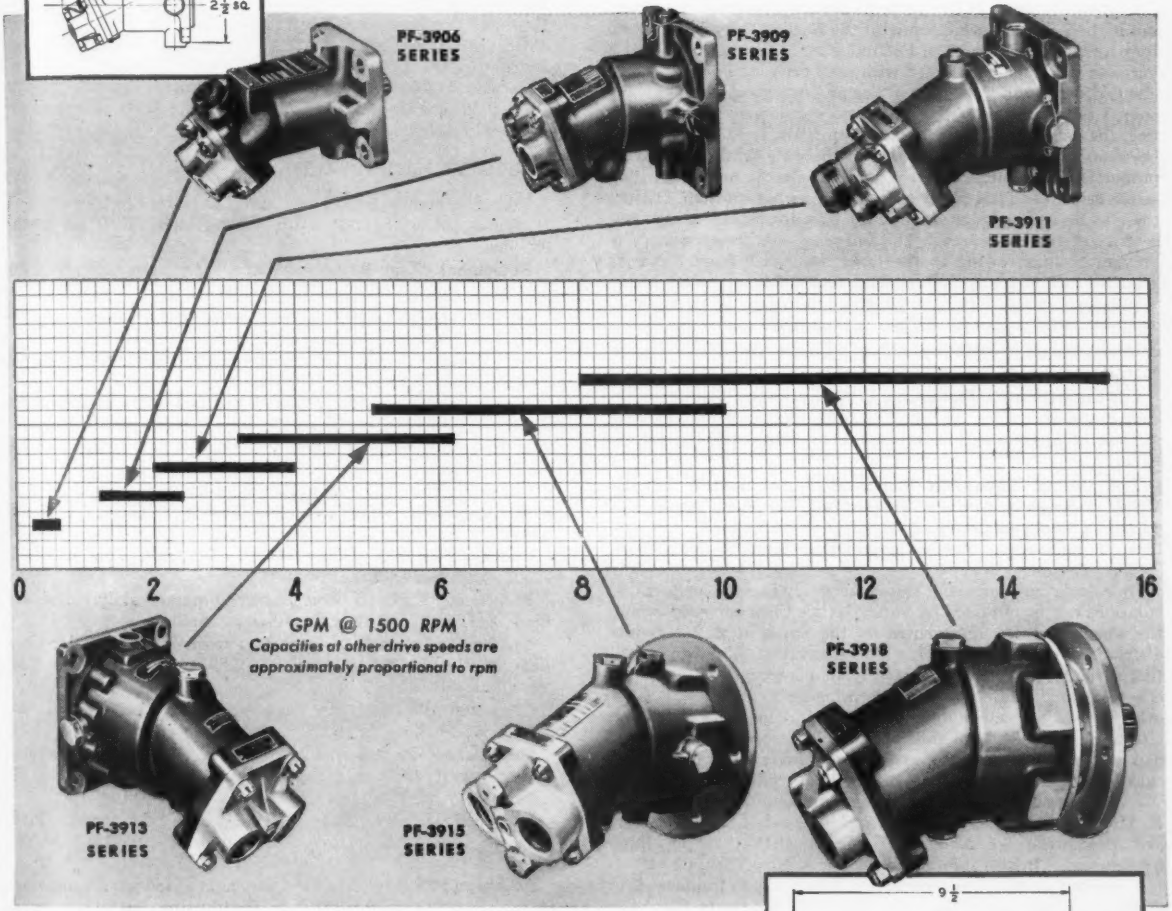

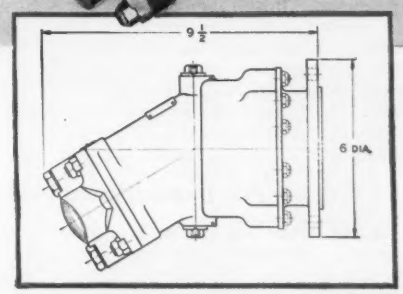

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An Analysis of the Lift Slope of Aerofoils of Small Aspect Ratio, Including Fins, with Design Charts for Aerofoils and Control Surfaces. D. J. Lyons and P. L. Bisgood. *Gt. Brit., Aeronautical Research Council, Reports and Memoranda No. 2308*, 1950 (January, 1945). 19 pp., illus. 21 references. British Information Services, New York. $1.15.

A method of estimating the lift characteristics of all airfoil controls and main controls of an aircraft which give the lift slope, taking into account interference effects, to within ±5 per cent and the control powers to within ±10 per cent.

Model Tests on a High-Lift Aircraft, Folland E28/40. I—Tests on Aileron. II—Tests on Tailplane. III—Resultant Force on Wing Slat. A. S. Halliday, D. K. Cox, and W. C. Skelton. *Gt. Brit., Aeronautical Research Council, Reports and Memoranda No. 2428*, 1950 (April, 1943). 77 pp., illus. British Information Services, New York. $3.00.

Combined results of five separate series of experiments carried out in the 7-ft. No. 2 wind tunnel at the National Physical Laboratory from 1941–1943. The Folland E28/40, as proposed, had a variable incidence wing fitted with a 40 per cent Fowler flap for about 65 per cent of the span. The proportions of the aileron departed somewhat from those hitherto considered normal practice, the chord being much wider than normal, 40 per cent, and the span short, about 28 per cent of the wing semispan. These proportions were necessary to accommodate the maximum span of the flap. The tail plane was also somewhat unusual, because there was a leading-edge slat and the elevator formed a high percentage of the total area. The tail-plane slat was necessary to prevent stalling, owing to the large downwash from the wing when set at a high angle of incidence and with engine on.

Readers' Forum: On a Variational Principle in Lifting-Line Theory. Alexander H. Flax. *Journal of the Aeronautical Sciences*, Vol. 17, No. 9, September, 1950, pp. 596, 597. 7 references.

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By calculating equivalent slopes, accuracy in wing-loading calculations can be obtained by vortex lattice theory in cases where the wing cannot be represented by the slopes at a few points distributed over the surface. The equivalent slopes are such that, when used with comparatively simple solutions, the major effects of irregularities or distortion, wing twist, deflected flaps, or other causes are adequately represented. Only the chordwise effects are considered. Values of equivalent slopes for a deflected flap, applicable to one, two, or three chordwise terms, have been calculated and tabulated for a range of flap-chord ratios.

A New Family of Low Drag Wings with Improved C_L-Ranges. B. Thwaites. *Gt. Brit., Aeronautical Research Council, Reports and Memoranda No. 2292*, 1950 (March, 1945). 29 pp., illus. 5 references. British Information Services, New York. $1.25.

A method of designing symmetric airfoils which produces lift-coefficient ranges larger than those of any previous airfoils of the same thickness-chord ratio. The first nine of a new family of airfoils, designated MR, have been derived from the "rooftop" airfoil. Each has a lift-coefficient range larger than its counterpart in the N.A.C.A. 6 series.

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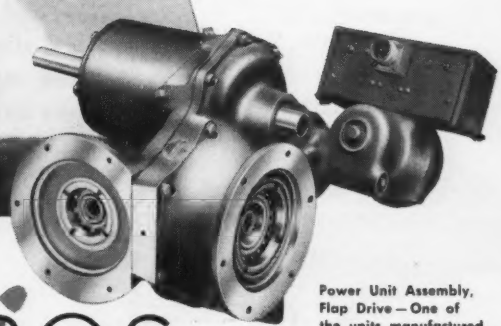

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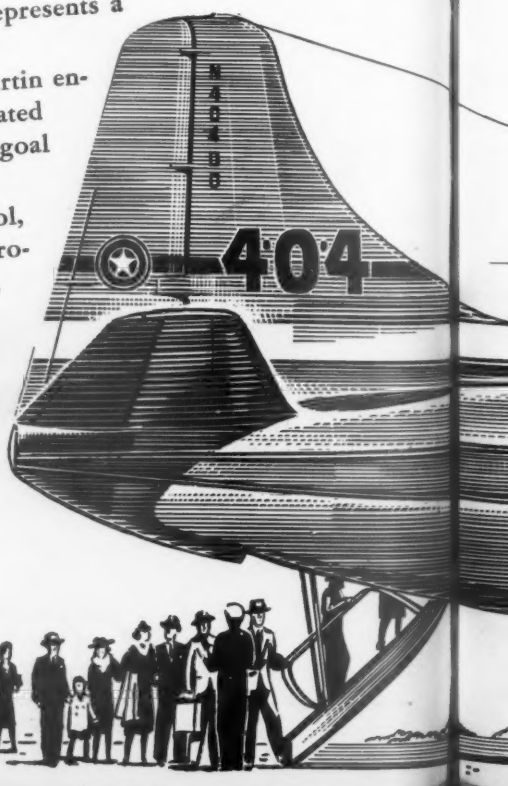

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Comfortization (23)

Cooling Aircraft Cabins on the Ground. *The Aeroplane*, Vol. 79, No. 2041, July 21, 1950, p. 88, illus. A portable ground air-conditioning unit developed for B.O.A.C. by Sir George Godfrey and Partners.

Education & Training (38)

The Development of an Evaluation Procedure for Training Aids and Devices (Human Engineering Synthesis of Basic Information). Harold A. Edgerton, Douglas H. Fryer, and others. Richardson, Bellows, Henry & Co., Inc. *U.S., Navy, Office of Naval Research, Special Devices Center, Technical Report No. SDC 383-2-1*, June 15, 1950. 22 pp., illus.

Evaluation of the School Link and Special Methods of Instruction in a Ten-Hour Private Pilot Flight-Training Program. Ralph E. Flexman, William G. Matheny, and Edward L. Brown. *Illinois, University, Institute of Aviation, Aeronautics Bulletin No. 8*, July, 1950. 44 pp., illus.

The Link Trainer—How It Works. *The Aeroplane*, Vol. 78, No. 2034, June 2, 1950, pp. 638–643, illus., cutaway drawings.

Electronics (3)

Matrix Telemetering System. Nolan R. Best. *Electronics*, Vol. 23, No. 8, August, 1950, pp. 82–85, illus. System permits transmission of 30 channels of information with an overall accuracy of 1 per cent. Data voltages determine position of pulses in 30 accurately-timed intervals, traversed sequentially and in synchronism at both sending and receiving stations.

An FM/FM Telemetering System. W. J. Mayo-Wells. *Instruments*, Vol. 23, No. 7, July, 1950, pp. 717, 718, illus.

Slot Radiators. Nicholas A. Begovich. *Institute of Radio Engineers, Proceedings*, Vol. 38, No. 7, July, 1950, pp. 803–806, illus.

The electromagnetic fields throughout all of space produced by an excited finite-length slot in an infinite-extent, perfectly conducting metallic sheet have been calculated by the double current sheet diffraction formula. The space dependence of the fields is the same as that of a thin-wire antenna, but with the electric and magnetic fields interchanged. An integration of Poynting's vector over the surface of the slot gives an input resistance of 363 ohms for a center-driven half-wave-length slot. The mutual admittance between slots necessary in slot array calculations is also determined.

Characteristics and Adjustment of 335-Megacycle Equisignal Glide Slopes. Sidney Pickles. *Electrical Communication*, Vol. 27, No. 2, June, 1950, pp. 140–151, illus. 1 reference.

ILS-2 Instrument Landing Equipment. R. A. Hampshire and B. V. Thompson. *Electrical Communication*, Vol. 27, No. 2, June, 1950, pp. 112–122, illus.

Modification of A.R.I. 5272 Aircraft Radio Set. *Electrical Communication*, Vol. 27, No. 2, June, 1950, pp. 138, 139, illus. A V.H.F. radiotelephone communication set for naval aircraft.

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Auto-Sembly Systems of Circuit Fabrication. *U.S., Central Air Documents Office (Navy-Air Force), Technical Data Digest* Vol. 15, No. 6, June 1, 1950, pp. 24–26.

Stagger-Tuned I-F Design. Matthew T. Lebenbaum. *Electronics*, Vol. 23, No. 8, August, 1950, p. 102, illus. Chart gives overall bandwidth for 3 db. and any fraction of 3 db., for i.f. amplifiers having 1 to 500 synchronous or stagger-tuned stages and up to 5 elements per stage.

Beam Deflection Nonlinear Element. Aaron S. Soltes. *Electronics*, Vol. 23, No. 8, August, 1950, pp. 122, 174, 176, 178, illus.

Radar Instruments with Elimination of Fixed Obstacle Indication. H. V. Tanter. *Interavia*, Vol. 5, No. 5, 1950, pp. 255, 256, illus.

Microwave Attenuation Statistics Estimated from Rainfall and Water Vapor Statistics. Howard E. Bussey. *Institute of Radio Engineers, Proceedings*, Vol. 38, No. 7, July, 1950, pp. 781–785, illus.

The Uniform Line Tube. J. T. Fleck and H. G. Iddings. *Cornell Aeronautical Laboratory, Inc., Report No. UC-630-P-1*, February 28, 1950. 11 pp., illus. 4 references.

The Solution of Lagrangian Frequency Equations with Complex Coefficients or Roots by the Escalator Method; The Application of the Method to Problems Connected with Flutter and Radio Circuits. J. W. Head. *Aircraft Engineering*, Vol. 22, No. 254, April, 1950, pp. 104, 105, 108, illus. 5 references.

An Extension of Wiener's Theory of Prediction. Lotti A. Zadeh and John R. Ragazzini. *Journal of Applied Physics*, Vol. 21, No. 7, July, 1950, pp. 645–655, illus.

Equipment

"Jetliner" (Avro) Equipment Reflects U.S. Manufacturers. Charles E. Corby. *Aero Digest*, Vol. 61, No. 1, July, 1950, pp. 44, 45, 75, illus.

ELECTRICAL (16)

Lighting the "Stratocruiser." R. J. Helberg. *Aero Digest*, Vol. 61, No. 1, July, 1950, pp. 36, 37, 91, 92, illus. 2 references.

Electrics (Rotax) for the (Airspeed) Ambassador. *The Aeroplane*, Vol. 79, No. 2040, July 14, 1950, pp. 54–57, illus.

HYDRAULIC & PNEUMATIC (20)

Critical Buckling Loads for Hydraulic Actuating Cylinders. Fred Hoblit. *Product Engineering*, Vol. 21, No. 7, July, 1950, pp. 108–112, illus.

Procedure for computing critical buckling loads for hydraulic actuators of a cylinder and piston rod where compression force is transmitted over a part of the column length by fluid pressure. Buckling loads are analyzed using moments and forces acting on a free body with cylinder fluid both included and excluded.

Evolution of Naval Aircraft Hydraulic Systems. James E. Sullivan. *Aero Digest*, Vol. 61, No. 1, July, 1950, pp. 42, 43, 92, 93, illus.

Flight Operating Problems (31)

ICE PREVENTION & REMOVAL

A Rapid Method of Estimating the Severity of Icing. S. S. Schaetzel. *Aircraft Engineering*, Vol. 22, No. 257, July, 1950, pp. 186–190, illus.

A method of three-dimensional plotting by which the rate of catch of water droplets at any station on the wing of an aircraft is plotted vertically on a base representing the maximum icing condition. By plotting the isothermal lines on the base and on the surface representing the rate of catch, an immediate estimate of the maximum rate of heat supply at a given temperature is made possible. By plotting those maxima against the ambient temperature, the most severe icing condition can be established.

Improvements in Heat Transfer for Anti-Icing of Gas-Heated Airfoils with Internal Fins and Partitions. Vernon H. Gray. *U.S., N.A.C.A., Technical Note No. 2126*, July, 1950. 44 pp., illus. 13 references.

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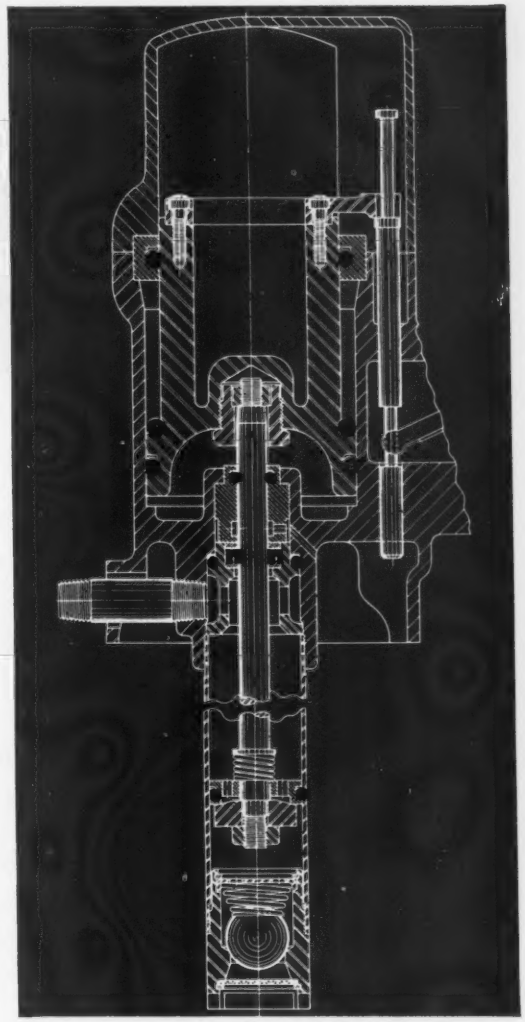

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Jet Engine Icing Protection Systems. II. Randolph Hawthorne. *Aviation Operations*, Vol. 14, No. 1, July, 1950, pp. 24, 25, illus. 6 references.

REFUELING IN FLIGHT

Flight Refuelling and the Problem of Range. C. H. Latimer-Needham. *Royal Aeronautical Society, Journal*, July, 1950, pp. 433–463, illus.

An analysis of the principles of flight refueling which shows the relationship of pay load to range and the effect of range on aircraft size in both military and civilian applications. A detailed study of the economics of a de Havilland Comet nonstop service between New York and London shows that potential profits increase rapidly when flight refueling is used on flights of over 2,000 still-air miles. With any aircraft, refueling in flight makes it possible to realize profits at ranges well in excess of its maximum profitable range under normal operation.

Flight Safety & Rescue (15)

Accident Statistics Can Contribute to Safer Flying. Jesse W. Lankford. *Mechanical Engineering*, Vol. 72, No. 7, July, 1950, pp. 553–555, 558. 10 references. A discussion of C.A.B. accident statistics for air carriers and nonair carriers.

More Air Traffic with Greater Safety. S. P. Saint. *Mechanical Engineering*, Vol. 72, No. 7, July, 1950, pp. 556–558. 10 references. A review of development in the "common" air-navigation and traffic-control system.

Safety Regulations and Accident Investigation: Jurisdictional Conflicts of C.A.B. and C.A.A. Edward C. Sweeney. *Journal of Air Law and Commerce*, Vol. 17, No. 2, Spring, 1950, pp. 141–150. 2 references.

Safety for Automotive Equipment. Jerome Lederer. *Aero Digest*, Vol. 60, No. 6, June, 1950, pp. 64, 76, 77, illus. Airport vehicles.

Landing Gear Fires Studied by C.A.A. *Aviation Week*, Vol. 53, No. 1, July 3, 1950, pp. 27, 28.

Fire Resistant Finishes for Aircraft. J. A. Jones and R. V. Niswander. (*A.S.T.M. Paper*, October, 1949.) *Aircraft Engineering*, Vol. 22, No. 254, April, 1950, pp. 109–112, illus.

Simplified Crash Fire Switch. *Aviation Week*, Vol. 53, No. 1, July 3, 1950, pp. 31, 32, illus. A piston-actuated mechanism developed by Groviner Mfg. Co., Ltd., which is to be produced by Simmonds Accessories, Inc.

U.S.A.F. Buying New Fire Detector. *Aviation Week*, Vol. 53, No. 2, July 10, 1950, p. 17, illus. The Fireye, a radiant energy sensitive cell developed by Photoswitch, Inc.

"Mobile Can-Opener" for Crashed Planes. John Loughlin. *Indian Skyways*, Vol. 4, No. 4, April, 1950, p. 3, illus. A spearhead mounted on an armored patrol car for cutting open the fuselage of crashed airplanes to extricate passengers.

Fuels & Lubricants (12)

Photographs of Sprays from Pressure Jets. A. Simons and C. R. Goffe. *Gt. Brit., Aeronautical Research Council, Reports and Memoranda No. 2343*, 1950 (September, 1946). 13 pp., illus. British Information Services, New York. $0.95.

Correlation of Physical Properties with Molecular Structure for Dicyclic Hydrocarbons: I—2-*n*-Alkylbiphenyl, 1,1-Diphenylalkane, α,ω-Diphenylalkane, 1,1-Dicyclohexylalkane, and α,ω-Dicyclohexylalkane Series. P. H. Wise, K. T. Serijan, and I. A. Goodman. *U.S., N.A.C.A., Technical Note No. 2081*, May, 1950. 33 pp., illus. 12 references.

The Oxidation, Ignition, and Detonation of Fuel Vapors and Gases. XIV—The Cause of the Effect of Hydrogen Sulphide to Reduce the Compression Ratios at Which Fuel Gases Can Be Used in Spark Ignition Engines. XV—The Concentration of Finely Divided Carbon in Two Gas-Air Mixtures Required to Induce Severe Knocking Combustion. R. O. King, E. J. Durand, and A. B. Allan. *Canadian Journal of Research*, Vol. 28, No. 6, June, 1950, pp. 166–188, illus. 22 references.

Fuel for Commercial Jets. A. R. Ogston. *Aero Digest*, Vol. 60, No. 6, June, 1950, pp. 17, 18, 97–100, illus.

Dicyclic Hydrocarbons. I—Alkylbiphenyls. Irving A. Goodman and Paul H. Wise. *American Chemical Society, Journal*, Vol. 72, No. 7, July, 1950, pp. 3076–3079. 14 references.

Gliders (35)

Low-Speed Model Tests on a "U" Wing. J. Trouncer and G. F. Moss. *Gt. Brit., Aeronautical Research Council, Reports and Memoranda No. 2295*, 1950 (July, 1945). 16 pp., illus. 2 references. British Information Services, New York. $0.75.

The effects of the end fins and the split flaps on a model "U"-wing tailless glider were in good agreement with those obtained with a "V"-wing plan form. The addition of the fuselage, however, caused a severe breakaway to occur in the wing fuselage junction. Center section slats remove this breakaway, but the resulting pitching-moment curve is unstable above a lift coefficient of 0.7 or thereabouts. The maximum trimmed lift on the wing above is 1.12 with the stability neutral or slightly unstable above a lift coefficient of 0.8.

On Sailplanes with Auxiliary Propulsion. II. A. R. Weyl. *Sailplane and Glider*, Vol. 18, No. 7, July, 1950, pp. 154–158, illus.

The Slingsby Prefect Intermediate Sailplane. J. C. Reussner. *Aircraft Engineering*, Vol. 22, No. 257, July, 1950, pp. 204–208, illus., cutaway drawings. 5 references.

Guided Missiles (1)

An Analysis of Base Pressure at Supersonic Velocities and Comparison with Experiment. Dean R. Chapman. *U.S., N.A.C.A., Technical Note No. 2137*, July, 1950. 69 pp., illus. 11 references.

Instruments (9)

Design Considerations for a Proposed Lift-Coefficient Indicator. E. N. Brailsford. *Aircraft Engineering*, Vol. 22, No. 257, July, 1950, pp. 194–196, illus. 7 references.

A summary of the advantages to be obtained by replacing the pilot's air-speed indicator by a lift-coefficient indicator. Such an instrument would utilize the relationship between airfoil-surface pressures, the angle of attack, and the Mach Number and would have an accuracy of approximately 1 per cent in all atmospheric conditions.

The Hot-Wire Anemometer in Supersonic Flow. Leslie S. G. Kovasznay. *Journal of the Aeronautical Sciences*, Vol. 17, No. 9, September, 1950, pp. 565–572, 584, illus. 7 references.

Hot Wire Anemometry; Solution of Some Difficulties in Measurement of Low Water Velocities. George B. Middlebrook and Edgar L. Piret. *Industrial and Engineering Chemistry*, Vol. 42, No. 8, August, 1950, pp. 1511–1513, illus. 11 references.

Stick-Force Indicator Simplifies Testing. *Aviation Week*, Vol. 53, No. 4, July 24, 1950, pp. 34, 36, illus. Developed at N.B.S.

The Absorption-Emission Pyrometer, A New Type of Instrument for the Measurement of High Flame Temperatures. Donald H. Jacobs and S. Scholnick. *North American Aviation, Inc., Aerophysics Laboratory, Memorandum No. 100* (*Report No. AL 100*), January 21, 1947. 27 pp., illus. 7 references.

The theoretical basis, operation, and calibration of a pyrometer for measuring rocket exhaust-flame temperatures which utilizes the absorptive and emissive properties of the particles in the flame.

A Note on the Use of Resistance Thermometers for Measurement of Rapidly Changing Temperatures. C. B. Daish, D. H. Fender, and A. J. Woodall. *Philosophical Magazine*, Vol. 41, No. 318, July, 1950, pp. 729, 730.

Instrument for Measuring the Wall Shearing Stress of Turbulent Boundary Layers. H. Ludwieg. *U.S., N.A.C.A., Technical Memorandum No. 1284*, May, 1950. 22 pp., illus. 9 references.

What to Consider When Selecting a Metallic Bellows. A. H. Ellis and J. H. Howard. *Product Engineering*, Vol. 21, No. 7, July, 1950, pp. 86–89, illus.

Sensing Small Motions; with Variable Reactors; with Differential Transformers. T. R. Breunich. *Product Engineering*, Vol. 21, No. 7, July, 1950, pp. 113–116, illus.

Magnetic Powder Clutches Speed Servo Response. *Product Engineering*, Vol. 21, No. 7, July, 1950, pp. 131–133, illus.

Analyzing Contactor Servomechanisms by Frequency-Response Methods. R. J. Kochenburger. *Electrical Engineering*, Vol. 69, No. 8, August, 1950, pp. 687–692, illus. 6 references. An approximation method for performance prediction or fulfillment of design specifications. The method is particularly adaptable for selecting compensating networks to improve performance.

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Indicating Instruments at Servo Frequencies. W. S. Pritchett and R. M. Saunders. *Electrical Engineering*, Vol. 69, No. 8, August, 1950, p. 705, illus.

Gage Detects Coating Thickness; Electronic Unit Uses Probe Coil, Inductance Principal for Checking Ceramins, Paints on Non-Magnetic Metal. *Aviation Week*, Vol. 53, No. 2, July 10, 1950, pp. 30, 31, 34, illus. Developed at N.B.S. under N.A.C.A. sponsorship.

Streak Photography. Irwin Vigness and R. C. Nowak. *Journal of Applied Physics*, Vol. 21, No. 5, May, 1950, pp. 445–448, illus. 2 references.

When there are components of motion which cause image displacements in the direction of motion of the recording film used in streak photography, a small rigid body is attached to the object whose motion is being studied. One or more parallel lines, which are perpendicular to the principal component of motion and are contained in the focal plane of the camera, are scribed on this body. The image of these lines on the camera film is cut to an approximate point by introducing a slit or a slit and cylindrical lens near the film. Transient displacements of many inches can thus be measured to an accuracy of a few thousandths of an inch. The time scale can be extended to more than a second with an accuracy up to about 10 microsec.

Un Nouveau Dynamomètre de Torsion. Necdet Eraslan. *Istanbul, University, Faculty of Science, Review, Series A, Mathematics, Physics, and Chemistry*, Vol. 15, No. 2, April, 1950, pp. 124–126, illus.

An Approach to Helicopter Instrumentation. Joseph A. Cannon and Owen Q. Niehaus. *Aero Digest*, Vol. 61, No. 2, August, 1950, pp. 24, 26, 28, 100–102, illus.

Flight tests show that the conventional instrumentation of fixed-wing aircraft is adequate for flying helicopters on instruments at speeds in excess of 40 m.p.h. For slower speeds, more sensitive instruments must be developed. For take-off and landing, navigation aids must be adapted to the steep approach path of the helicopter.

Flying Helicopters by Instruments. John S. Fay. *American Helicopter*, Vol. 18, No. 6, May, 1950, pp. 8–12, 21, 22, illus.

Laws & Regulations (44)

The Air Route Pattern Problem. Russell B. Adams. *Journal of Air Law and Commerce*, Vol. 17, No. 2, Spring, 1950, pp. 127–140. 26 references.

Safety Regulations and Accident Investigation: Jurisdictional Conflicts of C.A.B. and C.A.A. Edward C. Sweeney. *Journal of Air Law and Commerce*, Vol. 17, No. 2, Spring, 1950, pp. 141–150. 2 references.

Aviation Contributions to the Development of International Cooperation—Internationalization: Objectives and Methods. Institut Français du Transport Aérien. *Journal of Air Law and Commerce*, Vol. 17, No. 2, Spring, 1950, pp. 185–193.

Principles and Extent of Liability Under the Revision of the Rome Convention Proposed by the I.C.A.O. Legal Committee. G. Nathan Calkins, Jr. *Journal of Air Law and Commerce*, Vol. 17, No. 2, Spring, 1950, pp. 151–169. 25 references.

Law of Carriage by Air. J. W. Swann. *Institute of Transport, Journal*, Vol. 23, No. 11, July, 1950, pp. 359–364.

Liability of Air Carriers for Misconduct by Employees. Alex Meyer. *Interavia*, Vol. 5, No. 5, 1950, p. 251.

Liability of the Ground Control Operator for Negligence. Samuel Ewer Eastman. *Journal of Air Law and Commerce*, Vol. 17, No. 2, Spring, 1950, pp. 170–183. 80 references.

Machine Elements (14)

BEARINGS

Investigation of 75-Millimeter-Bore Cylindrical Roller Bearings at High Speeds. I—Initial Studies. E. Fred Macks and Zolton N. Nemeth. *U.S., N.A.C.A., Technical Note No. 2128*, July, 1950, 54 pp., illus. 7 references.

Nylon in Bearings and Gears. William C. Wall. *Product Engineering*, Vol. 21, No. 7, July, 1950, pp. 102–107, illus.

FRICTION

Relation Between Friction and Adhesion. J. S. McFarlane and D. Tabor. *Royal Society (London), Proceedings, Series A, Mathematical and Physical Sciences*, Vol. 202, No. 1069, July 7, 1950, pp. 244–253, illus. 11 references.

Simultaneous measurements of the friction and adhesion of steel sliding on indium in air show that at first a minute tangential force is required to initiate relative motion since the junctions between the surfaces are already plastic under the applied load. As the relative motion proceeds, the region of contact grows, and the required tangential force and the adhesive force increase. An upper steady state is reached where the tangential force increases more rapidly than the rate of growth of the region of contact. The sliding then becomes macroscopic. The detailed behavior of the interface functions during the early stages of the sliding process may be expressed quantitatively in terms of von Mises' criterion for plastic deformation under combined normal and tangential stresses. A cold welding process actually occurs at the points of intimate contact and is responsible for both friction and the adhesion.

Adhesion of Solids and the Effect of Surface Films. J. S. McFarlane and D. Tabor. *Royal Society (London), Proceedings, Series A, Mathematical and Physical Sciences*, Vol. 202, No. 1069, July 7, 1950, pp. 224–243, illus. 26 references.

Adhesion between clean hard surfaces is not absent because of the nonformation of metallic junctions but because the released elastic stresses break the junctions one by one as the load is removed. With soft metals (lead or indium), marked adhesion is observed if the surfaces are free of contamination. This adhesion provides direct evidence of the formation of metallic junctions by a process of cold welding. If the surfaces are covered with oxide films, the amount of metallic interaction is diminished with a corresponding reduction in adhesion. Lubricant films have a similar effect, and, in general, those materials that are most effective in reducing adhesion are also most effective as boundary lubricants in reducing friction.

Influence of Interfacial Potential on Friction and Surface Damage. F. P. Bowden and L. Young. *Research*, Vol. 3, 1950, pp. 235–237, illus. 12 references. (Reprint.)

Small changes in the interfacial potential of inert metals immersed in an electrolyte have a profound effect on friction and surface deformation. The friction is a minimum in the region of oxygen decomposition. It rises to a maximum at a potential of approximately 0.3 volt on the H_2 scale and falls again in the region of hydrogen decomposition. This effect is attributed to the electrodeposition and electrosolution of adsorbed gas layers and to the electrical interaction of the charged double layer.

Effect of Chemical Reactivity of Lubricant Additives on Friction and Surface Welding at High Sliding Velocities. Edmond E. Bisson, Max A. Swikert, and Robert L. Johnson. *U.S., N.A.C.A., Technical Note No. 2144*, August, 1950. 33 pp., illus. 12 references.

SHAFTS & ROTATING DISCS

Asymmetrical Bending of Tapered Disks. C. F. Gradwell. *Aircraft Engineering*, Vol. 22, No. 257, July, 1950, pp. 209–212, illus. 3 references.

The bending of a disc, such as a gas-turbine rotor, that has a tapered bore built-in at the inner edge and has the outer edge plane and circular. The outer edge is considered either to impose a condition on the slope of the middle surface or to require zero circumferential bending moment. It was found possible to integrate the differential equation involved if the thickness varied as some power of the radius. If the variation is linear, an exact solution cannot be obtained, but the given profile may be replaced by one of a family of profiles to obtain an approximate solution.

TRANSMISSIONS, CLUTCHES, AND DRIVES

Giunti Idrodinamici. Corrado Casci. (*L'Ingegnere*, No. 9, September, 1947, pp. 630–636.) *Turin, Politecnico, Laboratorio di Aeronautica, Pubblicazione No. 213*, 1948. 7 pp., illus. 6 references. Hydrodynamic couplings.

Maintenance (25)

Maintaining the (de Havilland) Comet; Notes on the First 250 Hours of Flight Experience. Rex King. *de Havilland Gazette*, No. 57, June, 1950, pp. 2–6, illus.

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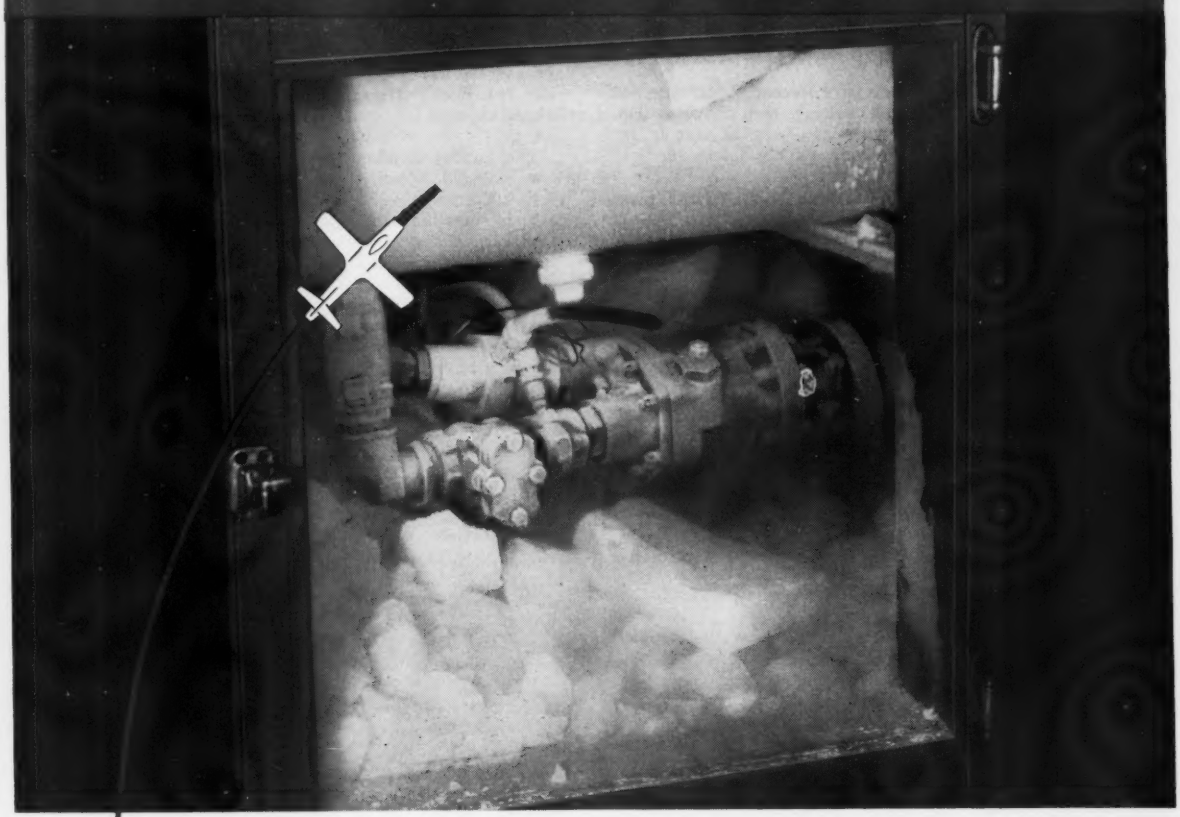

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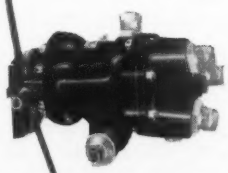

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Servicing Problems of the Middle East Air Force. James Hay Stevens. *Aircraft Engineering*, Vol. 22, No. 255, May, 1950, pp. 132–141, illus.

Production-Line Reconditioning. Willis L. Nye. *Aero Digest*, Vol. 61, No. 1, July, 1950, pp. 66, 67, 78, illus.

Easier Way to Strip Fuel Tanks; New Turco Method Breaks Bond Holding Sealant to Tank. *Aviation Week*, Vol. 52, No. 23, June 5, 1950, p. 43, illus.

A Servicing Innovation; Details of a Recent Modification to the Fairey Firefly. *Aircraft Engineering*, Vol. 22, No. 253, March, 1950, p. 84, illus. 1 reference. Redesign of wing undersurfaces for easier access by providing quickly detachable hole covers and hinged covers.

Boeing Service Guide, No. 34, July, 1950. 8 pp., illus. Model 377 Stratocruiser.

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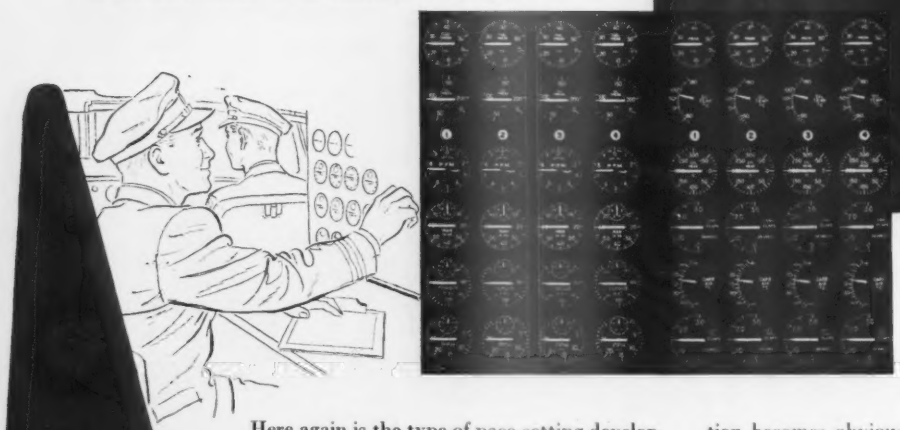

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Contains charts giving the take-off thrust of propellers of Clark Y section of 6 per cent, 7.5 per cent, and 9.3 per cent thick-

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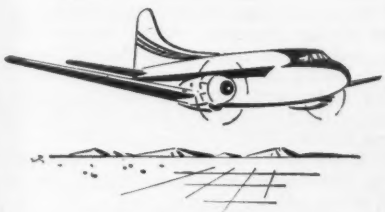

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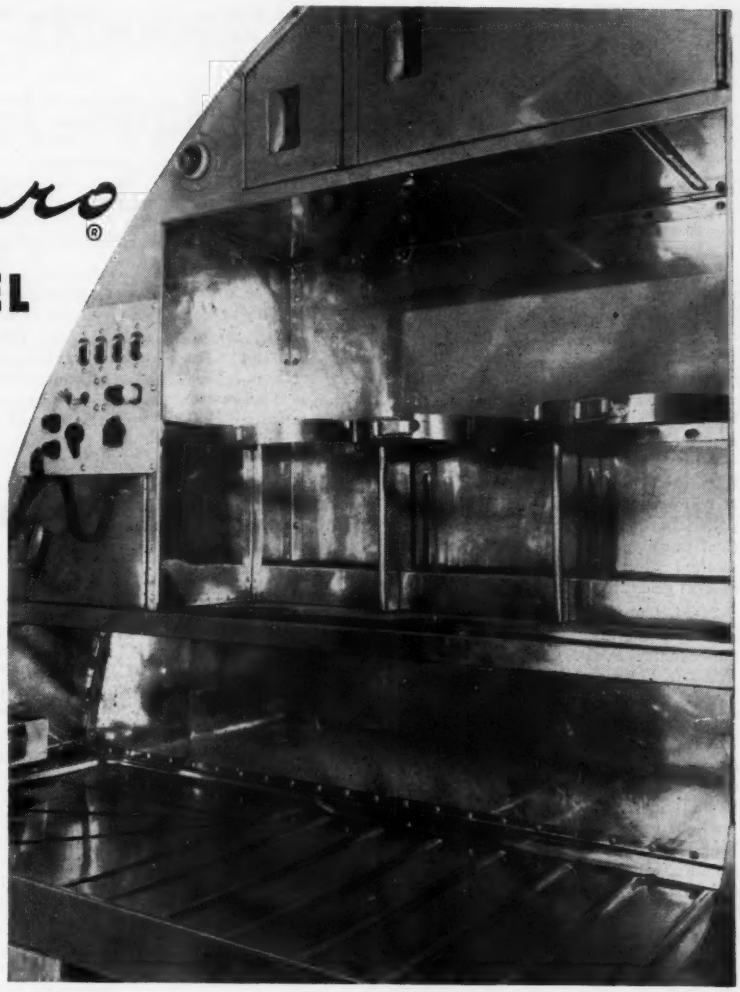

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ness ratio at 0.7 radius. The charts for 7.5 per cent thick propellers are a revised and extended version of those given as Chart I in *R. & M. 2086*. This earlier report should, however, still be used when considering Clark Y 12½ per cent thick propellers or R.A.F. 6 sectioned propellers. An approximate method is given for predicting the performance of stalled propellers of different thickness and pitch distributions.

A Comparison of the Measured and Calculated Twist Along a Propeller Blade. A. B. Haines. *Gt. Brit., Aeronautical Research Council, Reports and Memoranda No. 2360*, 1950 (July, 1946). 8 pp., illus. 9 references. British Information Services, New York. $0.50.

A comparison is made between values of blade twist found experimentally in the Royal Aircraft Establishment 24-ft.tunnel and calculated by the method of *R. & M. 1274*. The agreement achieved for two operating conditions at a tip Mach Number of 0.75 was reasonably good using existing data (extrapolated) for the centers of pressure of the sections. This agreement could be made close if it were assumed (as is suggested by the experimental results themselves and by data from airfoil tests in the R.A.F. High Speed Tunnel) that the center of pressure positions of the tip sections thinner than 6 per cent moved forward with increase of Mach Number up to the above value. It will be possible to calculate the twist of any other metal propeller that is not shock stalled to an accuracy sufficient for practical purposes. Analysis of experimental twist results by this method in order to produce center of pressure data would however in general be too laborious.

24-Ft. Tunnel Tests on a Rotol Wooden Spitfire Propeller; Test Results, and Data for Single Radius Calculations. A. B. Haines and P. B. Chater. *Gt. Brit., Aeronautical Research Council, Reports and Memoranda No. 2357*, 1950 (April, 1946). 11 pp., illus. 7 references. British Information Services, New York. $0.65.

Investigation of Reversing Propeller Pitch on a Multi-Engine Aircraft In Flight. Herbert O. Fisher. *S.A.E., National Aeronautic Meeting (Spring), New York, April 17–20, 1950, Preprint.* 16 pp., illus.

Flight tests with a C-54 showed that when the propellers are equipped with constant speed governors any combination of propellers or all four propellers can safely be reversed in flight. This technique permits descents from 20,000 ft. to be accomplished in 2 to 3 min. in comparison with the 7 min. required using normal procedures.

Application of Theodorsen's Theory to Propeller Design. John C. Crigler. *U.S., N.A.C.A., Report No. 924*, 1949. 17 pp., illus. 8 references. U.S. Govt. Printing Office, Washington. $0.15.

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The top and bottom outer layers of the Flex-O-Prop propeller blade have their wood fibers at 45° to the tip-to-tip direction so that the pitch angle will be diminished in response to an increase in propeller thrust.

Analytical Propeller Balance. S. Y. Tung. *Aircraft Engineering*, Vol. 22, No. 254, April, 1950, p. 113, illus. A simple practical method in use in the propeller shop of the Central Air Transport Corporation in China.

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Instruction and Research at the Daniel and Florence Guggenheim Jet Propulsion Center (CalTech). Hsue-Shen Tsien. *American Rocket Society, Journal*, No. 81, June, 1950, 51–64, illus. 14 references.

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Contents: Engine Starting (Automotive) at Low Temperatures, Fuels and Lubricants Laboratory. Current Projects in Aerodynamics Laboratory, Aircraft and Allied Instrument Laboratory, Engine Laboratory, Flight Research Section, Hydraulics Laboratory, Low Temperature Laboratory, Structures Laboratory, and Supersonics and Gas Dynamics Section. Note on Aeronautical Library. Note on Technical Translations.

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An analysis of 25 model tests showed that the ground effect expressed as a relative increase of lift at constant power depends on the ratio of the height above the ground to the rotor diameter and the mean lift coefficient of the blade measured outside the ground cushion. Flight test data obtained with a Sikorsky R-4B verified the generalized curves obtained.

An Explanation of Some Important Stability Parameters That Influence Helicopter Flying Qualities. Alfred Gessow and Kenneth B. Amer. *Aeronautical Engineering Review*, Vol. 9, No. 8, August, 1950, pp. 28–35, illus. 5 references.

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An Approach to Helicopter Instrumentation. Joseph A. Cannon and Owen Q. Niehaus. *Aero Digest*, Vol. 61, No. 2, August, 1950, pp. 24, 26, 28, 100–102, illus.

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Flying Helicopters by Instruments. John S. Fay. *American Helicopter*, Vol. 18, No. 6, May, 1950, pp. 8–12, 21, 22, illus.

Balsa Dust Shows Rotor Flow Geometry; Inexpensive Apparatus Is Developed by N.A.C.A. for Helicopter Research. *Aviation Week*, Vol. 53, No. 1, July 3, 1950, p. 25, illus.

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The Solution of Lagrangian Frequency Equations with Complex Coefficients or Roots by the Escalator Method; The Application of the Method to Problems Connected with Flutter and Radio Circuits. J. W. Head. *Aircraft Engineering*, Vol. 22, No. 254, April, 1950, pp. 104, 105, 108, illus. 5 references.

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MECHANICS

The Whirling of a Spinning Top. J. Morris. *The Aeronautical Quarterly*, Vol. 2, Part 1, May, 1950, pp. 9–14, illus. 2 references.

A contribution to the dynamics of contra-propeller systems and high-speed prime movers. The ordinary symmetrical top

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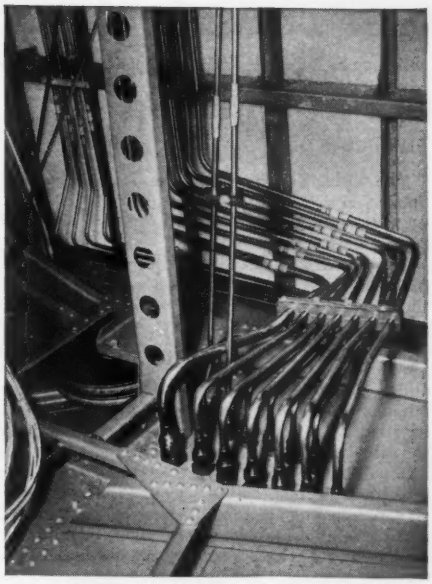

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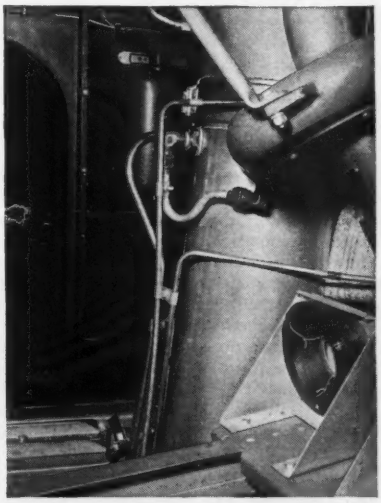

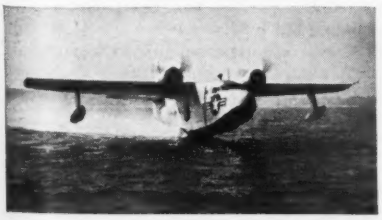

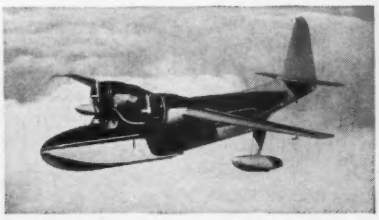

(Left) Grumman JR2F *Albatross.* Air-sea rescue amphibian built by Grumman Aircraft Engineering Corp., Bethpage, L. I., N. Y. *(Center)* Grumman *Mallard.* This is the first amphibian to pass the latest, most stringent Civil Aeronautics Administration's tests to qualify for a "Scheduled Air Carrier Operations" rating. *(Right)* MONEL tubing used for fuel pressure lines in the Grumman *Mallard.*

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has only one whirling speed, which is above the minimum speed for stability in the vertical position. The unsymmetrical top, however, in certain circumstances, may have two whirling speeds between which the unforced disturbed motion is exponentially unstable. For the inverted symmetrical top the disturbed steady motion will be exponentially stable at all speeds. It can have but one real whirling speed and that only if the moment of inertia about the axis of rotation is less than the moment about one of the other principal axes.

MECHANICS—VIBRATION

Dynamic Balancing and Its Application to Production Problems. T. Child and A. Binns. *The Engineer*, Vol. 190, No. 4930, July 21, 1950, pp. 54–56, illus.

PHYSICS

The Virial Equation of State. R. Byron Bird and Ellen L. Spotz. *Wisconsin, University, Naval Research Laboratory, Department of Chemistry, Report No. CM-599*, May 10, 1950. 36 pp., illus. 54 references.

The Lennard-Jones potential was used to prepare tables of functions from which the second and third virial coefficients and their temperature derivatives for any nonpolar gas may be calculated if the parameters in the potential function are known for that gas. Similarly the Stockmayer potential has been used to prepare tables of functions from which the second virial coefficient and its temperature derivatives for any polar gas may be computed if the force constants in the potential function are known for the gas. If experimental compressibility data are available, the tables enable one to gain information about the nature of the intermolecular force law and to extrapolate the experimental data into the high temperature region. It is possible, lacking values of experimental compressibilities, to combine the information about the intermolecular force fields obtained from viscosity measurements with theoretical calculations to predict the *p-v-t* behavior of gases.

Space Travel

Perturbations of a Satellite Orbit. Lyman Spitzer. *British Interplanetary Society, Journal*, Vol. 9, No. 3, May, 1950, pp. 131–136. 4 references.

Structures (7)

The Anti-Symmetric Vibrations of Aircraft. R. W. Traill-Nash. *Australia, Department of Supply and Development, Aeronautical Research Laboratories, Report No. SM. 149*, March, 1950. 19 pp., illus. 5 references.

It is assumed that pure antisymmetric vibrations of an aircraft can exist, involving fuselage torsion but excluding fuselage bending. With this assumption, which in most cases is a reasonable approximation, the eigenvalue equations for antisymmetric vibrations of a complete aircraft are derived in a general form. The "lumped-mass" approximation to the continuous mass distribution is used, and submatrices are associated with properties of relatively simple branches of the system. The final eigenvalue equations are expressed in terms of these submatrices so that in a numerical application the physical system as such is considered only in relation to the properties of the simple branches. It is assumed initially that the aircraft wing and tail have flexural axes of the conventional type, but the treatment is generalized to cover swept and cranked wing aircraft.

Application of Ritz's Energy Method to Problems in the Vibration, Buckling and Bending of Rectangular Plates. Dana Young. *Texas, University, Defense Research Laboratory*, April 30, 1949. 28 pp., illus. 10 references.

Tabulated values of the functions that represent the normal modes of vibration of a uniform beam and tables of values of different integrals of the functions and their derivatives are used to determine the vibration, buckling, and bending of rectangular plates. The method is applicable to the analysis of rectangular fins.

A Recurrence Matrix Solution for the Dynamic Response of Elastic Aircraft. John C. Houbolt. *Journal of the Aeronautical Sciences*, Vol. 17, No. 9, September, 1950, pp. 540–550, 594, illus. 6 references.

The Solution of Lagrangian Frequency Equations with Complex Coefficients or Roots by the Escalator Method; The Application of the Method to Problems Connected with Flutter and Radio Circuits. J. W. Head. *Aircraft Engineering*, Vol. 22, No. 254, April, 1950, pp. 104, 105, 108, illus. 5 references.

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The Calculation of Modes and Frequencies of a Modified Structure from Those of the Unmodified Structure. Edwin T. Kruszewski and John C. Houbolt. *U.S., N.A.C.A., Technical Note No. 2132*, July, 1950. 23 pp., illus. 1 reference.

Measurements of Twisting Moment Due to Aileron Deflection on a Model Mustang Wing at High Speeds. G. F. Hughes. *Gt. Brit., Aeronautical Research Council, Reports and Memoranda No. 2359*, 1950 (July, 1946). 10 pp., illus. 3 references. British Information Services, New York. $0.50.

Diagrams of Critical Flutter Speed for Wings of a Certain Standard Type. A. I. Van de Vooren and J. H. Greidanus. *Netherlands, Nationaal Luchtvaartlaboratorium, Report No. V.1297 (Verslagen en Verhandelingen*, Vol. 13, pp. V1–V18), 1947. 18 pp., illus. (In English.)

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Experimental Determination of the Aerodynamic Derivatives for Flexural-Aileron Flutter of B.A.C. Wing Type 167. C. Scruton, W. G. Raymer, and D. V. Dunsdon. *Gt. Brit., Aeronautical Research Council, Reports and Memoranda No. 2373*, 1950 (May, 1945). 15 pp., illus. 8 references. British Information Services, New York. $0.75.

The Change in Flutter Speed Due to Small Variations in Some Aileron Parameters. A. I. Van de Vooren. *Netherlands, Nationaal Luchtvaartlaboratorium, Report No. V.1380 (Verslagen en Verhandelingen*, Vol. 13, pp. V53–V58), 1947. 6 pp., illus. 3 references. (In English.)

Diagrams of Flutter, Divergence and Aileron Reversal Speeds for Wings of a Certain Standard Type. A. I. Van de Vooren. *Netherlands, Nationaal Luchtvaartlaboratorium, Report No. V.1397 (Verslagen en Verhandelingen*, Vol. 13, pp. V59–V69), 1947. 11 pp., illus. 4 references. (In English.)

The Treatment of a Tab in Flutter Calculations Including a Complete Account of Aerodynamic Coefficients. A. I. Van de Vooren. *Netherlands, Nationaal Luchtvaartlaboratorium, Report No. V.1386 (Verslagen en Verhandelingen*, Vol. 13, pp. V117–V131), 1947. 15 pp., illus. 10 references. (In English.)

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Sulla Torsione dei Prismi con Sezione di Parallelogramma. Riccardo F. Baldacci. (*Pisa, Università, Instituto di Scienza delle Costruzioni, Pubblicazione No. 3*, November, 1947.) *Pisa, Università, Facoltà di Ingegneria, Pubblicazione No. 540*, 1949. 11 pp., illus. Torsion of a prism of parallelogrammatic cross section.

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The Warping and Constraint of Certain Rectangular Box Sections. M. Fine. *Aircraft Engineering*, Vol. 22, No. 256, June, 1950, pp. 172, 173, illus. 3 references.

A theoretical investigation of the relation between the magnitude of the warping, the applied force, and the structural constraints, and of the ratio between the rotation and the flexure caused by constraint in a transversely loaded thin-walled shell that is unisymmetrical, prismatical, rectangular in section, and such that the sectional shape is maintained. The walls resist shear alone, and the capacity to resist longitudinal stress is concentrated at four booms along the corner generators. The load is applied parallel to the unequal walls.

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Torsional and Lateral Buckling of Eccentrically Compressed I and T Columns. Henrik Nylander. (*Kungliga Tekniska Högskola, Handlingar Nr. 28,* 1949.) *Acta Polytechnica (Stockholm), No. 54 (Civil Engineering and Building Construction Series,* Vol. 1, No. 8), 1949. 31 pp., illus. Sw. Kr. 3.

Combined Bending and Torsion of Simply Supported Beams of Bisymmetrical Cross Section. Ove Pettersson. (*Kungliga Tekniska Högskola, Handlingar No. 29,* 1949.) *Acta Polytechnica (Stockholm), No. 55 (Civil Engineering and Building Construction Series,* Vol. 1, No. 9), 1949. 42 pp., illus. Sw. Kr. 3.50.

Normalized Orthogonal Deflexion Functions for Beams. W. J. Duncan. **Tables of Orthogonal Functions.** R. A. Fairthorne. **Tables of Green's Functions.** S. Kirkby. *Gt. Brit., Aeronautical Research Council, Reports and Memoranda No. 2281,* 1950 (August 8, 1946). 23 pp., illus. 6 references. British Information Services, New York. $1.15.

Use of normalized orthogonal displacement functions in the treatment of the problems on the static deflection of elastic bodies. The first three symmetric and the first two antisymmetric orthogonal functions, together with their first and second differential coefficients, are tabulated. Short double-entry tables give the deflections caused by isolated normal loads and by isolated bending couples applied to doubly built-in uniform beams.

Stress Distribution in the Flanges of Curved T and I Beams. Hans Bleich. (*Die Bautechnik, Beilage zur Zeitschrift "Der Stahlbau,"* Vol. 6, No. 1, January 6, 1933, pp. 3–6.) *U.S., Navy, David W. Taylor Model Basin, Translation No. 228,* January, 1950. 10 pp., illus.

Calculation of the Deformation of Two-Spar Wings with Shear-Resistant Skin. F. J. Plantema and A. Van der Neut. *Netherlands, Nationaal Luchtvaartlaboratorium, Report No. S.311 (Verslagen en Verhandelingen,* Vol. 13, pp. S1–S12), 1947. 12 pp., illus. 8 references. (In English.)

Repeated Loading and Fatigue Tests on a D.H. 104 (Dove) Wing and Fin. W. A. P. Fisher. *Aircraft Engineering,* Vol. 22, No. 256, June, 1950, pp. 166–171, illus.

In repeated loading tests to investigate the durability of Redux joints between skin and stringers, a D.H. 104 wing sustained repeated applications of different loadings between 1.5*g* and 4.37*g*. The wing subsequently sustained 3 million cycles at its first resonance frequency during which the bending moment at the point of support was roughly equal to $\pm 0.25g$ superimposed on a mean loading of 1*g*. It sustained 4.6 million cycles at its second resonance frequency with small fluctuations. The fin sustained 60,000 cycles in reversal of 33 per cent of the fully factored load and 30 cycles in reversal at 66.7 per cent. When the fin was vibrated at ± 10 per cent of the fully factored load, failure occurred in the port front spar attachment fitting after 2.3×10^6 reversals.

A Hydraulic Static Testing Apparatus. J. K. Haviland and G. F. W. McCaffrey. (*Canada, National Research Council, Division of Mechanical Engineering, Structures Laboratory, Report No. MM-213.*) *Aircraft Engineering,* Vol. 22, No. 254, April, 1950, pp. 100–103, illus. Equipment for carrying out strength tests on wings and other large structures.

The Application of the Resonance Vibration Method to the Fatigue Testing of Spot Welded Light Alloys Structures. R. Weck. Institute of Welding, Transactions, Vol. 13, No. 2, April, 1950, *Welding Research,* pp. 33r–38r, illus.

The General Instability of Stiffened Cylindrical Shells Under Axial Compression. A. Van der Neut. *Netherlands, Nationaal Luchtvaartlaboratorium, Report No. S.314 (Verslagen en Verhandelingen,* Vol. 13, pp. S57–S84), 1947. 28 pp., illus. 4 references. (In English.)

Collapsing Stresses of Circular Cylinders and Round Tubes. F. J. Plantema. *Netherlands, Nationaal Luchtvaartlaboratorium, Report No. S.280 (Verslagen en Verhandelingen,* Vol. 13, pp. S17–S36), 1947. 20 pp., illus. 34 references. (In English.)

Correspondence: The Analysis of Structures Consisting of Curved Members of Variable Section. B. D. Jones. **Reply.** B. Saravanos. *Aircraft Engineering,* Vol. 22, No. 257, July, 1950, pp. 198, 199, illus.

Recommendations for Numerical Solution of Reinforced-Panel and Fuselage-Ring Problems. N. J. Hoff and Paul A. Libby. *U.S., N.A.C.A., Report No. 934,* 1949. 29 pp., illus. 12 references. U.S. Govt. Printing Office, Washington. $0.20.

The Determination of the Principal Stress Differences at a Point in a Three Dimensional Photoelastic Model. H. T. Jessop and M. K. Wells. *British Journal of Applied Physics,* Vol. 1, No. 7, July, 1950, pp. 184–189, illus.

A method of finding the directions of the principal axes of stress at any point of a thin slice cut from a "frozen stress" model. Results are recorded by a stereographic projection. Includes a description of the universal tilting microscope stage with a brief investigation into the theory of its use.

Thermodynamics (18)

Effect of Intense Sound Waves on a Stationary Gas Flame. H. Hahnemann and L. Ehret. (*Zeitschrift für Technische Physik,* No. 10–12, 1943, pp. 228–242.) *U.S., N.A.C.A., Technical Memorandum No. 1271,* July, 1950. 34 pp., illus. 10 references.

Characteristics of Disk-Controlled Flame. E. A. DeZubay. *Aero Digest,* Vol. 61, No. 1, July, 1950, pp. 54–56, 102–104, illus. 8 references.

An investigation of the blowout velocity of flames in the wake of a bluff body showed that the phenomena of stabilized flames can be explained by aerodynamic and energy considerations. Blowout can be described by three variables: the fuel-air ratio, the Reynolds Number, and a size factor. Experimental data verified the basic results of previous investigators.

The Effect of Sound on Flames. Samuel Loshaek. *Wisconsin, University, Naval Research Laboratory, Department of Chemistry, Report No. CM-612,* May 27, 1950. 71 pp., illus. 39 references.

A 12.7-kc. sound was imposed on a laminar, propane-air Bunsen flame. The normal burning velocity and the gas velocity distribution remained unaltered by the sound field. A marked change, however, occurred in the stability limits and the penetration distance of the Bunsen burner flame. The change was directly proportional to the intensity of the sound. It is apparent that the quenching process at the wall of the burner tube is affected by the sound field. Therefore, the rate of diffusion of free radicals from the reaction zone to the walls of the burner tube is increased. The process of heat conduction to the wall is apparently unchanged. A quenching mechanism, based on heat conduction to the wall of the burner tube and diffusion of free radicals to the wall, is proposed to explain the experimental observations.

Re-Examination of Thermodynamic Fundamentals. Howard W. Emmons. *Mechanical Engineering,* Vol. 72, No. 6, June, 1950, pp. 475–478.

The Emission of Radiation from Diatomic Gases. I—Approximate Calculations. S. S. Penner. *Journal of Applied Physics,* Vol. 21, No. 7, July, 1950, pp. 685–695, illus.

A method of estimating approximately the radiant heat transfer from gaseous emitters in high-pressure combustion chambers. An average absorption coefficient is determined in terms of the integrated absorption for very small optical densities and for large total pressures where the spectral half-width is no longer small compared with the rotational spacing. A preliminary compilation is given of the theoretical results that are necessary for making rapid estimates of the emissivities over a wide temperature range for C, HI, HBr, HCl, and HF.

Effect of Reynolds Number in Turbulent-Flow Range on Flame Speeds of Bunsen Burner Flames. Lowell M. Bollinger and David T. Williams. *U.S., N.A.C.A., Report No. 932,* 1949. 8 pp., illus. 9 references. U.S. Govt. Printing Office, Washington. $0.15.

Water-Borne Aircraft (21)

Readers' Forum: Lift of Planing Surfaces. B. V. Korvin-Kroukovsky. *Journal of the Aeronautical Sciences,* Vol. 17, No. 9, September, 1950, pp. 597–599, illus. 6 references.

A Study of Water Pressure Distributions During Landings with Special Reference to a Prismatic Model Having a Heavy Beam Loading and a 30° Angle of Dead Rise. Robert F. Smiley. *U.S., N.A.C.A., Technical Note No. 2111,* July, 1950. 40 pp., illus. 11 references.

Wind Tunnels (17)

Wind Tunnel Corrections for the Two-Dimensional Theory of Oscillating Airfoils. E. Reissner. *Cornell Aeronautical Laboratory, Inc., Report No. SB-318-S-3,* April 22, 1947. 56 pp., illus.

(*Continued on page 92*)

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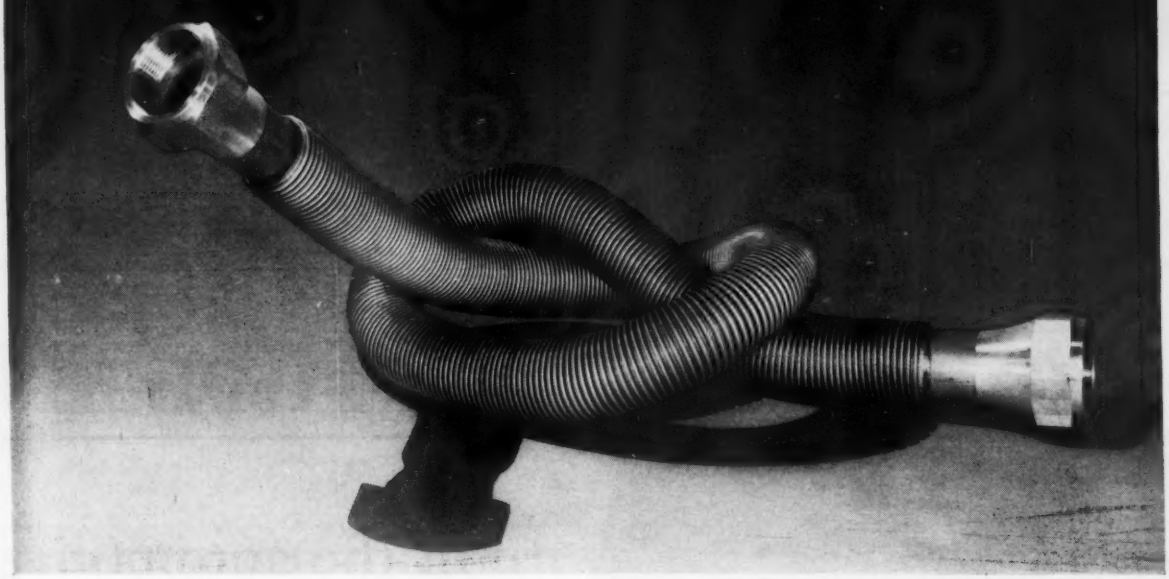

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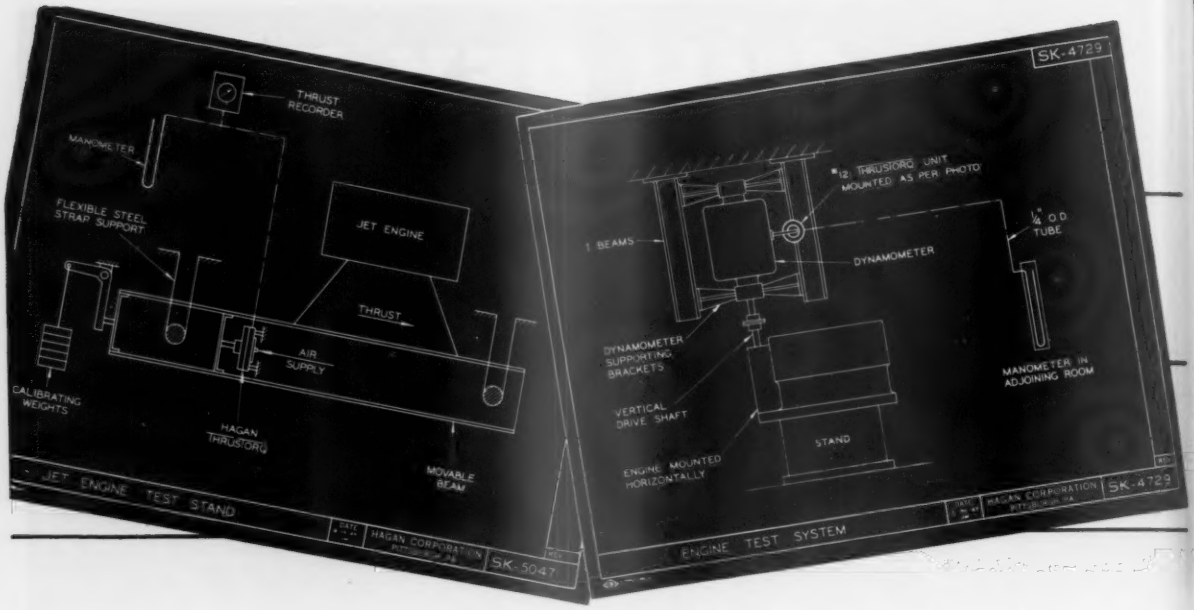

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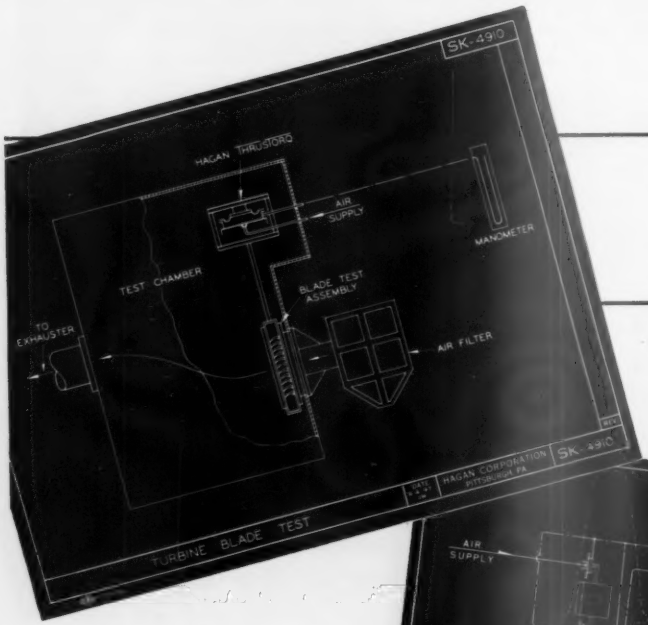

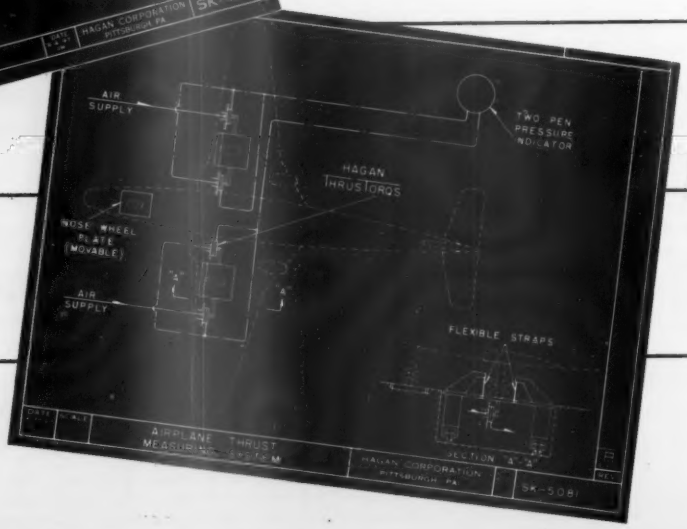

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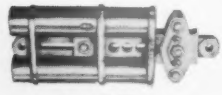

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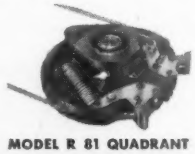

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Aeronautical Reviews — BOOKS

Deformation and Flow; An Elementary Introduction to Theoretical Rheology

By Markus Reiner. London, H. K. Lewis & Company, Ltd.; New York, Interscience Publishers, 1949. 346 pp., figs. $6.50.

It is probably safe to assume that many engineers who deal with structures and materials are not well acquainted with the term *rheology*. The word itself is based on the Greek word for stream, indicating that rheology is concerned with the flow of materials. In the preface of his book, Professor Reiner further describes rheology as belonging "to the phenomenological side of physics. It treats matter as it appears to our senses—i.e., as continuous." He also gives a clear picture of the relationship between rheology, as covered in his book, and the atomic-molecular approach (as exemplified by the work of Eyring). It is stated that the purpose of the present book is to assist investigators in material-testing laboratories. A book of this type is also of considerable interest to engineers who use materials in structures and machinery (it will be reviewed on this basis). Aeronautical engineers in particular will be interested in learning more about the flow of materials under load, because this phenomenon is the basis for inelastic theory, metal forming, etc. In the design of structures to operate at elevated temperatures, we must deal even more directly with the phenomenon of flow, whether it be called rheology, plasticity, or inelastic behavior.

Viewed in this light, the book appears to be limited in scope. Only part of the story of material behavior is told, which is, of course, the part commonly investigated by rheologists. What is badly needed today is a book which bridges the gaps between the various treatments of material behavior (e.g., physics of metals, elasticity, plasticity, and metallurgy) and which presents the important information in such a way that it can be understood and utilized by designers, stress analysts, and production engineers.

Perhaps because this is a book on rheology, the treatment of tension is deferred to Chapter X (p. 162), where Young's modulus is introduced for the first time. Up to this point everything is based on shearing stresses and strains. The shear modulus of elasticity ("modulus of rigidity") and the bulk modulus are regarded as fundamental constants, while Young's modulus and Poisson's ratio are regarded as derived constants. Perhaps it does not matter which two of the four constants are considered to be fundamental, but it has always seemed (to the reviewer) that Poisson's ratio, being a pure number, has a stronger claim on this title than does the modulus of rigidity.

In the discussion of the yield stress (defined as the shearing stress at which the material will begin to flow), there appears to be some difficulty with the minus sign. It is first assumed that the material is loaded until it starts to flow at some definite value of shearing stress. It is then (alternatively) assumed that the loading is reversed in direction so as to give the same value of shearing stress, but with a minus sign attached. The negative shear stress is then considered to be "less" than the critical (positive) value, and it is stated that the material therefore would not flow. From this it is concluded that: "This shows us that the quantity really governing the plastic flow is not of the nature of a stress, but something else which is proportional to the square of a stress."

It is later stated that the Mises-Hencky flow condition, which is based on elastic strain energy, does away with this difficulty, since the stress appears squared in the equation for elastic energy. It is true that the energy method eliminates the minus sign by multiplying the two minus quantities, but that would seem to be an incidental feature of the method—one which is common to all energy methods.

Suppose one applies the author's reasoning about the minus sign to the case of a block that will start to slide when a certain coefficient of friction is exceeded. The conclusion would be that sliding is not governed by the coefficient of friction but by something else which is proportional to the square of the coefficient. This does not seem to be the proper way to take care of the fact that the block can be pulled in either direction. In any event, this reviewer still feels that plastic flow is initiated by something that *is* of the nature of a stress.

An interesting discussion of power laws is presented in Chapter VI, from which the conclusion is drawn that the power formula "cannot be regarded as a true rheological equation but only as an interpolation formula. As such it is sometimes very useful." This accurately describes the use of the Ramberg-Osgood formula by aeronautical engineers (N.A.C.A. Technical Note No. 902). The physical actions that control the shape of the stress-strain diagram, although not yet thoroughly understood, are certainly too complex to be explained by a simple power formula. It should be noted that the Ramberg-Osgood formula expresses strain as a function of stress, which permits both the elastic and "plastic" portions of the strain to be indicated. Formulas that express stress as a function of strain do not seem to give the proper physical picture and could possibly have led to some of the confusion that has been associated with our efforts to understand the stress-strain diagram.

In Chapter VII there is again some difficulty with the minus sign. Here the discussion centers around finding an equation that will express viscosity (or fluidity) as a function of the shear stress. Certain exponents are ruled out because the sign of the stress is reversed if the direction of motion is reversed. This is equivalent to saying, for example, that the power required to propel an object through the air could not possibly vary as the cube of the air speed, because if the direction of flight were reversed, the power required would be negative! Considering the extent to which the various empirical equations are discussed, interpreted, and investigated, it seems strange that this small mathematical difficulty is permitted to have such a powerful effect. It appears in several other places in the book.

Chapters X, XI, and XII deal with simple tension, bending, and torsion. Here the subject matter is closely related to that usually covered in books and papers on strength of materials and plasticity. The phenomenon of strain hardening is defined as "the rise of the yield point of a material with increased deformation." The term

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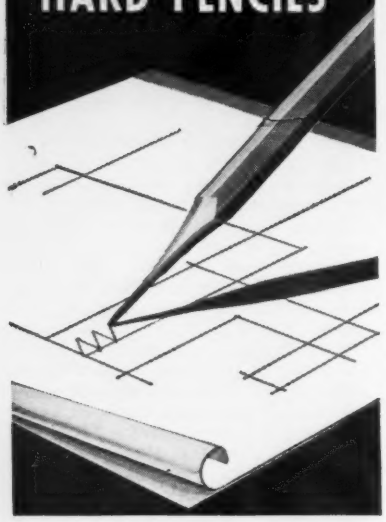

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"yield point," as used here, is meaningless unless the loading is reduced and then reapplied. There is no yield point on a smoothly curving stress-strain diagram. It would seem more logical, in investigating this phenomenon, to seek an explanation for the fact that the rate of strain increases with increasing stress. Recent investigations based on the concept of slip (for example, N.A.C.A. Technical Note No. 1871 by Batdorf and Budiansky) appear to be in the right direction. This reviewer is convinced that the "rheological" approach, based on the idea of a sharp dividing line between elasticity and plasticity, together with a definite "yield point" or "flow stress," has been responsible for delaying progress in the theory of inelastic behavior. Fortunately, this stumbling block has been pushed aside by many recent investigators.

In summarizing the discussion of work-hardening, the author states that "the rise of the yield point in the work-hardening range is due to the breaking up of large into small crystals." On this basis a "rheological equation" is proposed. Although this explanation may be partially correct for polycrystalline materials, it fails to account for the fact that "strain-hardening" is observed also for single crystals, as shown in Fig. 44, p. 70 of *The Physics of Metals*, by Seitz. There is no discussion of recent theories based on the concepts of dislocations or random distribution of weaknesses within the material. In the preface the author stated that he preferred to leave these aspects out entirely, instead of giving fragmentary accounts.

Most of the chapter on bending and torsion (Chapter XII) is devoted to the derivation of the well-known engineering equations for stresses and deflections. It is then pointed out that these results can also be used for viscous flow by replacing the values of elastic strain and modulus of elasticity by rate of strain and coefficient of viscosity, respectively.

Chapter XIII deals with creep, but the treatment is restricted entirely to concrete and mortar. This phenomenon is becoming more and more important in modern metal structures operating at high temperatures. Furthermore, creep may be regarded more generally as a basic action in which strain is produced by a constant stress acting over a period of time. In the opinion of this reviewer, the stress-strain diagram, usually considered as the starting point in studying the behavior of materials, is only the result of a special case of fairly rapid loading. At higher temperatures, the effects of time become important, and it would seem proper to work with strain-stress-time curves, which in their restricted form are called creep curves. Since metals were used as a basis for the discussion of work-hardening, it is somewhat surprising to find no discussion of metals in the chapter on creep.

The final chapters contain interesting discussions of relaxation, damping, delayed elasticity, dilatancy, and idealized models. The various theories of strength are described in some detail. The last chapter deals with notation. The

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TABLE 1
Comparison of Notation Systems

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Tensile stress	p_n	s	σ	s_{xx}	σ
Shear stress	p_t	S	τ	s_{xy}	τ
Tensile strain	e_n	σ	ϵ	ϵ_{xx}	ϵ
Shear strain	e_t	σ	γ	ϵ_{xy}	γ
Modulus of elasticity (tension)	ϵ	E	E	E	E
Modulus of elasticity (shear)	γ	n	G	G	G
Bulk modulus	κ	K	κ	K	K
Poisson's ratio	σ	π	μ	ν	μ

* Blair, W. Scott, *A Survey of General and Applied Rheology*, Pitman Publishing Corporation, New York.

† Houwink, R., *Elasticity, Plasticity, and Structure of Matter*, Cambridge University Press.

‡ Nadai, A., *Plasticity*, McGraw-Hill Book Company, Inc., New York.

** Timoshenko, *Strength of Materials*, D. Van Nostrand Company, Inc., New York.

author states that "a systematic system of notation has been attempted." The result is a system that seems to differ almost completely from most established systems, even those of other rheological authors. The author recommends that the reader, when studying a rheological paper, "translate the notation used by the author into a notation familiar to him—e.g., that of the present book." This reviewer found it necessary to translate the notation of the present book into one of those with which he was already familiar. A few of the most important symbols have been compiled in Table 1, which should be self-explanatory.

The publication of a book of this type compels the reviewer to consider the entire subject of rheology in relation to other established fields. The story of modern rheology is well told by Scott Blair in his little (but valuable) book *A Survey of General and Applied Rheology*. The Society for Rheology was formed in 1929, and the word "rheology" was chosen at that time. In view of this, it is somewhat difficult to understand the author's frequent use of terms such as "rheological test curve." These things all existed before the Society was formed.

Blair states that "the greater part of what is generally called rheology is concerned with stress-strain-time relations in such materials (solids and liquids) and with the influence of such factors as temperature on them." Certainly this is the same field in which investigators of strength of materials have been working for at least 200 years.

This reviewer is not concerned about the establishment of a new society or the adoption of a new word for an old phenomenon. We should be concerned, however, about any trend toward further compartmentalization of technical knowledge. The state of affairs inside of a piece of material under load does not change with each new group of investigators. Yet our technical literature generally shows only one view at a time: perhaps a metallurgical cross section, an x-ray diffraction ring, a stress-strain diagram, an atomic lattice, or a tensor equation. Real understanding requires that all of these views be brought together and tested one against another. The different schools of thought will then resolve into different levels of abstraction, each serving a different purpose, but not conflicting with the knowledge gained in the other levels.

F. R. SHANLEY
Professor of Engineering
University of California at Los Angeles

Applied Experimental Psychology; Human Factors in Engineering Design

By Alphonse Chapanis, Wendell R. Garner, and Clifford T. Morgan. New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd., 1949. 434 pp., figs. $4.50.

There is a great need for studies that attempt to relate the basic data from the various biological disciplines to the design and use of machines and equipment. This book is a significant contribution to that end. Its primary objective is to interpret and report fundamental research and applied tests in developing a science that can deal adequately with the design and operation of machines for human use. This book should be of interest to aeronautical engineers, especially those concerned with the design of equipment in the cockpit and control cabin of all types of aircraft. It is obvious throughout the book that the authors are more concerned with the subtitle than with the main title, possibly in deference to their own academic disciplines. In the reviewer's opinion, Human Factors in Engineering Design is preferable because the nature of the problems dealt with is, broadly speaking, human, implying that the whole man is involved and not any single academic discipline, such as psychology.

In the first chapter, it is brought out that applied experimental psychology developed primarily from time and motion studies, personnel selection, and the results of the psychological laboratory. It was then shown how the recent war imposed new demands on machines and on the men who operated them. Then follows a chapter on what is termed "a little statistics" and another on the application of statistics. The first should be useful to those requiring a few reference points in this field. The second one applies these facts in an original and suggestive manner to an analysis of constant and variable errors in the use of equipment by human operators. This material should be of interest to engineers who are not familiar with statistical methods. The illustrations of the statistical methods for studying complex man-machine relationships are novel and effective.

The next three chapters, 4, 5, and 6, deal with how we see, instrument dials and legibility, and visual displays from the point of view of ease and effectiveness of seeing. After discussing the physical stimuli involved in seeing, several factors that relate to visibility and visual acuity are elaborated. In discussing the use of the eyes at night and in daylight, the important role of age in night vision is neglected. This variable is probably of as great or even greater importance than many of those that are discussed.

In Chapters 5 and 6, on dials and legibility and visual displays, respectively, there is a great deal of information directly related to the problems of the aeronautical engineer. Many of their own and other experiments on dials, instruments, and displays are ably interpreted in relation to their use by operators. The discussion on errors in reading aircraft instruments (pp. 122–126), the patterning of instrument displays (pp. 150–154), and the relative advantages of pictorial vs. symbolic instrument displays in aircraft (pp. 156–162) should be of special interest to the designers of instruments.

In one part of Chapter 5, there is an attempt to reconcile two studies that gave diametrically opposed findings. No doubt those differences resulted from the nature of the experimental setup and are a warning to engineers that each specific design problem should be worked out experimentally in order to obtain a satisfactory solution. The generalizations thus far established are apt to be misleading unless this is done. This is especially true in regard to legibility of numbers and symbols on dials.

Chapters 7, 8, and 9, dealing respectively with hearing, speech, and tonal signaling systems, are equally as good as the previous ones in which the authors have contributed many original studies of their own. The physical properties of sound and the psychological aspects of hearing are discussed as background material for the reception of speech and signaling. Emphasis is placed on factors influencing the intelligibility of speech which should be of great value and interest to acoustical and communication engineers. The chapter on tonal signaling systems (pp. 242–262) also contains several interesting methods arising out of the war for taking the excessive burden from the eyes in the use of equipment. The analysis relating to the psychological problems in the use of radio range signals and flying by audi-

tory reference (Flybar) should give rise to improvements in hearing auditory signals in flight.

Chapters 10 and 11 relating to "how we make movements" and "controls for human use" deal with many new and original experiments in a greatly neglected field. It is clearly demonstrated that controls can be designed for safe and efficient use without necessarily seeing them. The part relating to blind positioning reactions (pp. 274–277) is of particular interest. Useful illustrations are given of how position, size, shape, and color can be employed to great advantage in identification and use of levers. The sections dealing with errors in using aircraft controls (pp. 298–301), the shape-coding of controls (pp. 311–315), and the analysis of control forces (pp. 316–318) are relevant to the designer of such equipment.

The main emphasis in Chapter 12 on the arrangement of work is how to make working areas safer and more efficient by proper grouping and sequences in the operation of controls. Here the authors call upon the valuable data of the physical anthropologist as well as experts in time and motion studies.

Chapter 13 is primarily concerned with the problem of fatigue, especially the decrements that are present in various types of activities or working situations. The final chapter on the working environment refers briefly to several variables, such as temperature and humidity, motion, noise, light, and color. These last two chapters are primarily a reconsideration of older material and do not include many of the important contributions that were made just before and during World War II.

This book is an important contribution to an understanding of the human factors in the design and operation of equipment, especially in relation to visual, auditory, and motor functions. It should receive the careful consideration of every aeronautical engineer in his attempt not only to prevent accidents but also to improve the ease and efficiency of operations.

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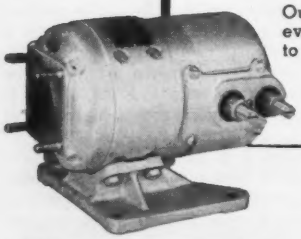

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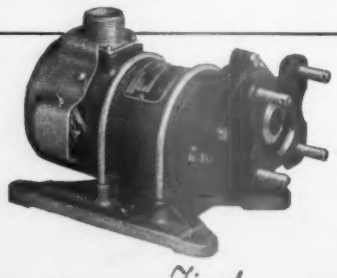

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Fundamentals of Power Plants for Aircraft

By Joseph Liston. Cincinnati, Tri-State Offset Company, 1950. Misc. paging, figs. $5.50.

Professor Liston has succeeded admirably in his attempt to prepare a textbook for undergraduate students in Aeronautical and Mechanical Engineering which will aid them to learn the fundamentals of aircraft power plants rapidly. His clearly presented discussions of characteristics, limitations, and possibilities of different types of aircraft power plants are of especial value at this time when the rapid development of thermal jet engines has forced revision of plans in the field of military and commercial aviation. The book has value to practical men as well as to engineering students because it presents a wealth of information in narrative form in addition to its numerous charts, formulas, and illustrations. Each chapter concludes with illustrative examples and helpful references. A suggested assignment schedule for a one-semester course in power plants is included. This should be useful to instructors in this subject.

Chapter I, Basic Requirements and Achievements. This section presents most of the basic formulas including lift, drag, horsepower, and thrust and discusses weight limitations, thermal efficiencies, operating life, and sources of power. A brief history of the development of aircraft engines is also included.

Chapter II, Utilization of Available Energy. Reciprocating engines, turbojets, athodyds, and rocket engines are covered in considerable detail in this chapter. Topics include velocity ratio; propeller efficiency; mechanical, thermal, and volumetric efficiency; effects of rotative speed, displacement, and pressure on power output; and the merits and shortcomings of current power-plant types.

Chapter III, Fuels. The subject of fuels is dealt with adequately. The origin and refining of petroleum, chemical structure and physical properties of gasoline and other fuels, methods of testing, octane numbers, and detonation phenomena are clearly explained and illustrated.

Chapter IV, Charge Handling. This covers fuel-system units, types and operation of carburetors and fuel injection systems, and comprehensive discussions of fuel-air ratio problems encountered in the operation of reciprocating and turbojet engines.

Chapter V, Cylinder Phenomena. This chapter includes the following topics: normal and abnormal combustion, Otto and Brayton cycles, comparison of spark-ignition and compression-ignition engines, cetane number, methods for observing and measuring cylinder phenomena, thermodynamic possibilities, and special features of jet engine combustion.

Chapter VI, Performance. Methods used to measure performance, including the instrumentation and types of equipment employed in determining pressure, temperature, volume, speed, and power output under all operating conditions, are described in this chapter.

Chapter VII, Turbine Engine Characteristics. The author amplifies previously discussed characteristics of gas-turbine engines and summarizes most of what was known of these types at the time of publication. He discusses problems awaiting solution in the rapidly advancing field of jet propulsion and points out the possibilities of turboprop-jets and thrust augmenters for improving take-off and climb characteristics.

This reviewer is of the opinion that the book suffers somewhat through the use of the photo-offset method of reproduction since a few of the charts are difficult to read. Conventional page numbering and a good index would also add something to what is otherwise an excellent textbook.

CHARLES C. GREENE
Aeronautics Teacher
Board of Education
City of New York

Book Notes

AIR TRANSPORTATION

The World's Airways and How They Work. J. W. G. James and John Stroud, Editorial Advisers. London, Odhams Press, Ltd., 1950. 320 pp., illus. 12*s.* 6*d.*

Air-route planning, existing air services, aircraft design and manufacture, piloting, navigation, power plants, maintenance, traffic control, landing aids, weather service, and present and future aircraft are discussed in twelve separate articles, each by a specialist. Technical information is simply explained and illustrated by some 300 photographs and more than 30 special drawings. This is an excellent and up-to-date survey of the working of the modern air line and the scope of air-transport services.

AIRPLANE DESIGN

Modern Aircraft Design. J. L. Nayler. London, Temple Press, Ltd., 1950. 122 pp., illus. 8*s.* 6*d.*

The author's aim is to give a description of the fundamentals behind the design of aircraft for those not directly engaged in that field. Introductory chapters outline the general trend of aircraft design and the steps involved in the development of an airplane. Aerodynamics and structures are reviewed in nontechnical language, and there is a

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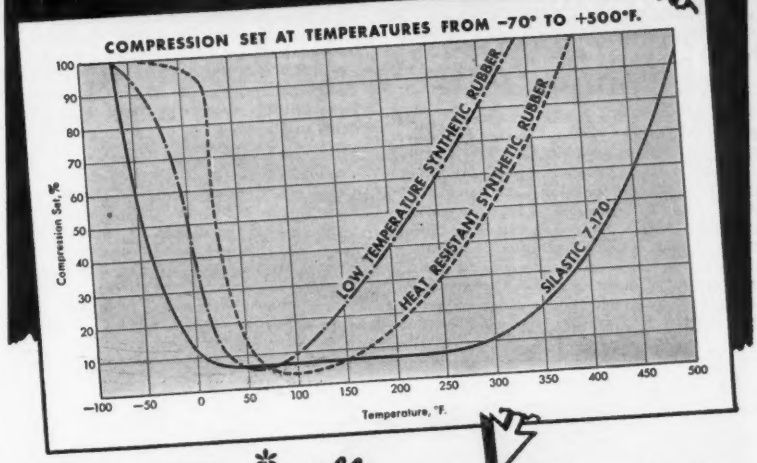

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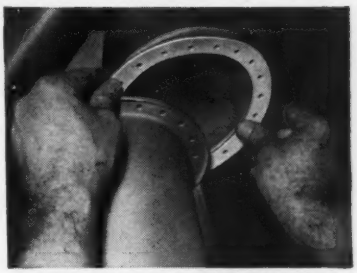

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separate chapter on auxiliary design problems, such as landing gears, pressurization, ice prevention, and instrumentation. The two final chapters cover examples of civil and military types of aircraft and problems of extremely high-speed and extremely low-speed design. The author is Secretary of the British Aeronautical Research Council.

ELECTRONICS

Theory and Design of Electron Beams. J. R. Pierce. New York, D. Van Nostrand Company, Inc., 1949. 197 pp., figs. $3.50.

The author aims to cover the principal theory of electron optics required for understanding of electron flow and electron focusing in devices other than electron microscopes and image tubes. The main emphasis is on applications to amplifier and oscillator tubes and particularly to microwave tubes. Problems are included as extensions of the text, and bibliographic notes are given throughout.

Outline of Radio, Television and Radar; a Symposium. Brooklyn, Chemical Publishing Company, Inc., 1950. 688 pp., figs. $12.

Beginning with a chapter on the nature of electricity and ending with a survey of radar, this book presents the fundamental principles underlying radio, television, and radar operation, and descriptions of apparatus and their various applications. There is a separate chapter on radio direction finding. The 26 chapters are written by eight British authorities. The book is well indexed and illustrated.

Wave Filters. L. C. Jackson. London, Methuen & Company, Ltd.; New York, John Wiley & Sons, Inc., 1950. 107 pp., illus. $1.25.

Designed for the student of physics or radio, this book is an introduction to the theory of wave filters, describing their types, design, and construction, and mechanical and acoustical applications of wave-filter theory. A bibliography of 20 books and basic articles is included. The author is with the H. H. Wills Physical Laboratory at the University of Bristol.

ENGINEERING PRACTICES

Engineering Drawing and Drawing Office Practice. P. S. Houghton. London, Crosby Lockwood & Son, Ltd., 1950. 277 pp., figs. 15*s*.

In this textbook, the purpose is to present standard methods of drafting practice in detail, with emphasis on an adequate number of views for a given component. The needs of the entire design and production cycle are kept in mind, including those of the estimator, time-study man, pattern maker, and the tool-room and production sections. Calculations on the strength of components are omitted. Sheet metal, pipe, gears, jigs and fixtures, fasteners, press tools, and castings are discussed in separate chapters, and drafting room conventions, checking, and management are other subjects included. The book was developed from practice and from courses taught by the author at Aston Technical College in Birmingham.

FUELS & LUBRICANTS

Natural Gas and Natural Gasoline. R. L. Huntington. New York, McGraw-Hill Book Company, Inc., 1950. 598 pp., figs. $8.00.

The natural gas and natural gasoline branches of the petroleum industry are discussed, with the student of petroleum, chemical, or mechanical engineering in mind, and also for the process and equipment designer. Chapters are included on storage and transportation, high-pressure pipeline research, and various physical principles involved. Test methods are given in appendixes. Professor Huntington teaches chemical engineering at the University of Oklahoma.

METEOROLOGY

Between Earth and Sky. Auguste Piccard. London, Falcon Press, 1950. 157 pp., illus. 15*s*.

Though this book is written for the layman, Professor Piccard's authority and his capacity for the exposition of theory in readable and attractive fashion make it an important addition to the literature of meteorology and space travel. The first part of his discussion is concerned with the physics of the atmosphere, including the role of humidity, selective radiation, clouds, observations and forecasting, and laminar and whirling flow. Five chapters are concerned with the stratosphere and ionosphere, where Professor Piccard speaks with unique authority. The three final chapters deal with such aspects of the future as atomic decomposition and new sources of energy, and interplanetary and interstellar travel. This translation from the original French is excellent.

NAVIGATION

The Complete Air Navigator. D. C. T. Bennett. 5th Ed. London, Sir Isaac Pitman & Sons, Ltd., 1950. 430 pp., illus., diagrs. 25*s*.

This new edition of a manual covering the syllabus for the first class air navigator's license was last completely revised in 1942, though a revised reprint of the 4th edition was issued in 1945. The present edition is larger by 52 pages and has been considerably rearranged, with new material added to cover advances made during World War II. Chapters on Visual Observations, Radio and Radar Observations, and Astronomical Observations have been added.

POWER PLANTS

Steam Turbines and Their Cycles. J. Kenneth Salisbury. New York, John Wiley & Sons, Inc., 1950. 645 pp., figs. $9.00.

This book originated from a course given by the author during World War II to graduate mechanical engineers, reviewing fundamental thermodynamics, flow of fluids, and the fundamentals of turbine design. This material is covered in Part 1 of the present book. Part 2, on the regenerative cycle, presents a conventional method of analysis and a short-cut method developed by the author and presented in a paper before the A.S.M.E.

in 1942. This material is greatly expanded in this section including derivations, curves, and design data. This is followed up in the third part on cycle analysis to include the effects of all minor variables on plant heat rate. The final section is concerned with application engineering including design details, estimating of steam rates, and estimating of heat rates. The author is with the General Electric Company.

PRODUCTION

Manufacturing Processes, Materials. S. E. Rusinoff. Chicago, American Technical Society, 1949. 393 pp., illus. $5.00.

Designed for the engineer and designer and the plant supervisor, this book deals with molding, casting, hot and cold forming, welding, brazing and soldering, and heat treatment, with two final chapters on powder metallurgy and plastics and plastic molding. A good index locates discussions of specific alloys and specific subjects such as accident prevention or the Guerin process. Bibliographies are included at the ends of chapters. The author is an Associate Professor of Mechanical Engineering at the Illinois Institute of Technology.

Engineering Precision Measurements. A. W. Judge. 2nd Ed. Revised. London, Chapman & Hall, Ltd., 1950. 363 pp., figs. 30*s*.

In this new edition of a book first published in 1944, a new section of 50 pages has been added on recent developments in precision measuring methods covering measuring machines, projectors, micrometers, new types of slip gages, thread gages, and internal measurement methods. Additional information is included on gear-testing appliances, the use of the interferometer in gage testing, the Dekker optical device, and the more recent electronic comparator for high-precision measurements. Supplementary information is given also on the aging of gage steels.

REFERENCE LITERATURE

BIBLIOGRAPHIES

S.A.W.E. Bibliography; A Survey of All Literature Pertaining to Weight Control Engineering or of Special Interest to the Weight Engineer. Society of Aeronautical Weight Engineers, Inc., Los Angeles Chapter, Culver City, Calif., c/o James A. Crabtree, Hughes Aircraft Company, 1950. (About 290 3- by 5-in. cards.) $15, including supplementary cards for 5 years.

This is an annotated bibliography on cards, classified under eleven main headings and 45 subdivisions, covering estimating procedures, weight control and reduction, flight loading methods and systems, weight distribution, moments of inertia and dynamic balance, hydrostatics, actual weighing methods and equipment, weight and c.g. calculation methods, air-line weight control, and forms and systems of bookkeeping. The references are dated mostly from 1941 to 1949, with a few of earlier years.

DICTIONARIES & ENCYCLOPEDIAS

Cross-Reference Dictionary of Abbreviations and Symbols. U.S., Department of the Army, Ordnance Department, Research and Development Division Suboffice (Rocket), Fort Bliss, Tex., Special Report, November, 1949. 191 pp.

Compiled to standardize usage at an installation engaged in guided-missile research and development, this dictionary combines abbreviations and symbols from twelve sources, including handbooks, textbooks, and American Standards. The inconsistencies among the sources used have been resolved according to the best common usage. Alternate usages are indicated in some cases, and symbols or abbreviations not sanctioned by common usage are so indicated. Part I is an alphabetical index to symbols and abbreviations, and Parts II and III list the English letter symbols and Greek letter symbols with their equivalents. About 2,000 abbreviations and symbols are included.

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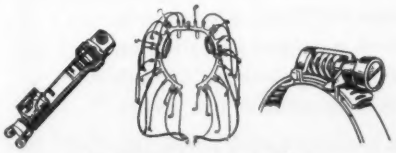

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Vocabulary. Bernard R. Regen and Richard R. Regen. Ann Arbor, Mich., J. W. Edwards, 1946. 358 pp. $6.00.

This excellent dictionary gives one or more meanings for about 21,000 German words in the field of electronics, offering a full coverage of the German vocabulary in this new field up to 1939, with numerous additions for the war years. Trade and scientific journals, books, and patent literature were used in compiling it, the original definitions being frequently worked over and clarified.

SCIENCES, GENERAL

MATHEMATICS

All Term Guide for Harmonic Analysis and Synthesis. L. W. Pollak, Assisted by U. N. Egan. (Ireland, Department of Industry and Commerce, Meteorological Service, Geophysical Publications, Vol. 2.) Dublin, The Stationery Office, 1949. 185 pp. £2 2*s*.

These tables supply schedules for all the natural sines and cosines, to five decimal places, required for the computation of harmonic constants (amplitude and phase) that can be derived from ($n = $) 3 to 24, 26, 28, 30, 34, 36, 38, 42, 44, 46, 52, 60, 68, 76, 84, and 92 equidistant values of empiric functions and for the synthesis of the periodic components that they define. In addition, the serial T-numbers given refer to the multiplication tables of the author's *Rechentafeln zur Harmonischen Analyse* (Leipzig, 1926), which makes it unnecessary to use a calculating machine, slide rule, or to perform the required multiplications mentally.

Fourier Series. G. H. Hardy and W. W. Rogosinski. 2nd Ed. (Cambridge Tracts in Mathematics and Mathematical Physics, No. 38.) London and New York, Cambridge University Press, 1950. 100 pp. $2.00.

In this new edition of a brief introduction to the general theory of Fourier series, originally published in 1944, corrections of misprints have been made, but there is no change in the text. The tract is written for the mathematician who is familiar with Lebesgue's theory of integration and wishes a concise introduction. The discussion is set forth in 100 theorems.

Problem Book in the Theory of Functions. Volume 1—Problems in the Elementary Theory of Functions. Konrad Knopp. Translated by Dr. Lipmen Bers. New York, Dover Publications, Inc., 1948. 126 pp. $1.85.

This translation is based on the second German edition, and refers to Dr. Knopp's *Theory of Functions*, Vol. 1, published in translation in 1945. The final chapter refers to C. Caratheodory's *Conformal Representation*, Cambridge, 1932. Part 1, of 39 pages, gives the problems, and Part 2, 87 pages, gives answers.

Proceedings of a Symposium on Large-Scale Digital Calculating Machinery, Jointly Sponsored by the Navy Department Bureau of Ordnance and Harvard University at the Computation Laboratory. (Harvard University, Computation Laboratory, Annals, Vol. 16.) Cambridge, Mass., Harvard University Press, 1948. 302 pp. $8.00.

Contents: The Work of Charles Babbage, Richard H. Babbage. Mark I Calculator, Richard M. Bloch. Brief Description and Operating Characteristics of the ENIAC, Lewis P. Tabor. Bell Telephone Laboratories' Relay Computing System, Samuel B. Williams. Mark II Calculator, Robert V. D. Campbell. Problems of Mathematical Analysis Involved in Machine Computations, Alexander W. Wundheiler. The Organization of Large-Scale Calculating Machinery, George R. Stibitz. Mercury Delay Lines as a Memory Unit, T. Kite Sharpless. Slow Electromagnetic Waves, Leon Brillouin. High-Speed Electrostatic Storage, Jay W. Forrester. Magnetic and Phosphor Coated Discs, Benjamin L. Moore. The Selectron—A Tube for Selective Electrostatic Storage, Jan Rajchman. Optical and Photographic Storage Techniques, Arthur W. Tyler. Method of Finite Differences for the Solution of Partial Differential Equations, Richard Courant. On Computational Techniques for Certain Problems in Fluid Dynamics, Raymond J. Seeger. Computational Problems Arising in Connection with Economic Analysis of Interindustrial Relationships, Wassily W. Leontief. On the Accumulation of Errors in Processes of Integration on High-Speed Calculating Machines, Hans A. Rademacher. Fluid Mechanics Computations, Howard W. Emmons. Firing Tables, L. S. Dederick. Coding for Large-Scale Calculating Machinery, Herman H. Goldstine. Preparation of Problems for EDV AC-Type Machines, John W. Mauchly. The Preparation of Problems for Large-Scale Calculating Machinery, Joseph O. Harrison, Jr. Application of Printing Telegraph Techniques to Large-Scale Calculating Machinery, Frederick G. Miller. Survey of Magnetic Recording, Otto Kornei. The Numeroscope, Harrison W. Fuller. Input and Output Devices for Electronic Digital Calculating Machinery, Samuel N. Alexander. An Input Device Using Multiple Gates, Morris Rubinoff. Photographic Methods of Handling Input and Output Data, R. D. O'Neal. Transfer Between External an Internal Memory, C. Bradford Sheppard. Publication, Classification, and Patents, Samuel H. Caldwell. Le Domaine du Calcul Mécanique, Louis Couffignal. New Vistas in Mathematics, Alan T. Waterman.

Punched Card Methods in Scientific Computation. W. J. Eckert. New York, Columbia University, The Thomas J. Watson Astronomical Computing Bureau, 1940. 136 pp., illus.

This book is designed to show applications of the Hollerith, or electric punched-card method, to computations in the physical sciences. The method is outlined, and the machines used are described in Part 1.. Part 2 is concerned with such applications as the construction and use of special tables of tabular functions, interpolation, mechanical quadrature and allied subjects, numerical harmonic analysis and synthesis, the multiplication of series, and the numerical solution of differential equations. The final part deals with astronomical applications.

MECHANICS

Mechanics Via the Calculus. 3rd Ed. P. W. Norris and W. Seymour Legge. London, Cleaver-Hume Press, Ltd.; New York, Dover Publications, Inc., 1950. 367 pp., figs. $3.95.

This standard textbook was first published in 1923 and was last revised in 1930. The present edition includes new material on vector analysis, the principal axes of inertia, and instantaneous center of rotation. The plan of previous editions is retained, and the material covered is the same, including statics, dynamics of a particle, rigid dynamics, and hydrostatics. The senior author was formerly with Alleyn's School at Dulwich and Mr. Legge with the Polytechnic in London.

Mechanics; A Textbook for Engineers. James E. Boyd and Percy W. Ott. 3rd Ed. New York, McGraw-Hill Book Company, Inc., 1950. 422 pp., diagrs. $4.50.

In this new edition of a textbook first published in 1921 and last revised in 1930, new chapters have been added on Machines and Friction, Method of Work, and Moving Frames of Reference. Much of the text has been rewritten, particularly the portions on forced vibrations and resonance, virtual work and the stability of systems of one degree of freedom, systems of forces in space to cover simple space frameworks, and the computation of moments in space by determinants. Applications rather than mathematical derivations are stressed in the problems, most of which are new. The authors are faculty members at the Ohio State University.

PHYSICS

Wave Mechanics. J. Frenkel. New York, Dover Publications, Inc. 1950. 2 Vols. Vol. 1, 312 pp., figs. $3.50; Vol. 2, 515 pp., figs. $5.00.

Professor Frenkel's general survey of wave mechanics was first published in 1934, and a revised edition of the first volume was published in 1936. The present work is a reissue of the two volumes. Volume 1, covering the elementary theory, deals with applications to light, matter

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wave mechanics of the motion of a particle in the field of force and of a system of particles, statistical mechanics, and applications of the quantum statistics to the electron theory of metals, heat motion, and radiation. The final chapter is devoted to the theory of chemical forces.

Volume 2, on the advanced general theory, covers classical mechanics as the limiting form of wave mechanics, operators and matrices, transformation theory and perturbation theory, relativistic remodeling and magnetic generalization of the wave mechanics of a single electron, and the problem of many particles. The two final chapters deal with the reduction of the problem of a system of identical particles to that of a single particle and second (intensity) quantization and quantum electrodynamics covering the work of Heisenberg, Pauli, and Dirac.

Methods of Mathematical Physics. 2nd Ed. Harold Jeffreys and Bertha Swirles Jeffreys Cambridge, New York, Cambridge University Press, 1950. 708 pp. $15.

In this new edition of a standard work first published in 1946, the discussion of the Heine-Borel theorem and Goursat's modification in Chapter 1 has been placed earlier and expanded. A discussion of block matrices has been added to Chapter 4, where the theorem on characteristic solutions of commuting matrices is also expanded. The chapter on multiple integrals has been completely rewritten, and a discussion of the theory of functions of several variables has been included. The discussion of relaxation methods has been extended, and revisions have been made of the proof of Cauchy's theorem, the proof of the Osgood-Vitali theorem, and the theory of inverse functions. Conditions for the truth of Watson's lemma have been relaxed, thus permitting it to cover almost all physical applications, and the method of stationary phase is more fully treated. The discussion of multipole radiation has been extended, and some new examples have been added. In general, proofs have been shortened and generalized.

Collision Processes in Gases. F. L. Arnot. London, Methuen & Company, Ltd.; New York, John Wiley & Sons, Inc., 1950. 104 pp., diagrs. $1.25.

Based upon lectures given at the University of St. Andrews in 1931–1932, this book is intended for advanced students and experimental physicists concerned with the collision of electrons, photons, and positive ions with atoms and molecules of a gas at low pressures. Phenomena whose study has been made possible by improved vacuum techniques are especially considered, where the effects of single collisions can be studied. A bibliography of about 128 references, arranged by chapters, is included.

STRUCTURES

An Introduction to Experimental Stress Analysis. George Hamor Lee. New York, John Wiley & Sons, Inc., 1950. 319 pp., figs. $5.50.

This textbook for an introductory course in experimental stress analysis is based on mimeographed notes for lectures given at the U.S. Naval Postgraduate School. The aim of the author is to present the commonly encountered methods of experimental stress analysis including theory, instrumentation, and basic techniques. Proceeding from an introductory chapter on the theory of elasticity, the discussion takes up stress determination from strain measurements and structural similitude. There are two chapters on strain gages and two chapters on photoelasticity, covering optical apparatus and experimental procedure. The final chapters deal with analogies, the brittle-lacquer method and various miscellaneous methods, ending with a discussion on experimental considerations. Selected bibliographies are given at the ends of chapters, and author and subject indexes are provided.

THERMODYNAMICS

Elements of Heat Transfer and Insulation. Max Jakob and George A. Hawkins. 2nd Ed. New York, John Wiley & Sons, Inc., 1950. 230 pp., illus., diagrs. $4.00.

In this new edition of a textbook intended for elementary courses, first published in 1942, additions and extensive revisions have been made affecting sixteen sections. Though the general structure of the work is unchanged, the authors have made it somewhat less elementary in method. A detailed section has been added on heat transfer by the combined effect on conduction and convection, and several graphs have been added in the discussion on log mean temperature differences in heat exchangers, for shell-and-tube heat exchangers, showing how correction factors are handled in practice in these complex cases. Some of the eleven new sections cover graphical and numerical methods for the analysis of conduction problems, heat transfer and fluid friction on plane surfaces, and conduction on the edges and corners of walls and on pieces of more complicated shape. The number of problems has been increased from 83 to 220. Problems on convection deal mostly with the substances air and water, and new tables of their properties have been included. Bibliographies are included at the ends of chapters.

I.A.S. Library Facilities

To serve Institute members and others in the aeronautical industry, the Institute of the Aeronautical Sciences offers the facilities of:

The W. A. M. Burden Library
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The Paul Kollsman Lending Library
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The Pacific Aeronautical Library
7660 Beverly Boulevard
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This is a service and reference library for West Coast organizations. Full information as to its facilities will be sent on request.

I.A.S. Sections

(*Continued from page 14*)

for the location of the Center. The Air Force is to design and procure the test equipment. The Corps of Engineers is to control the building of fixed installations and ground improvements.

It is estimated that 4 to 6 years will be required to complete the Center, based on the rate at which appropriations are made available. By 1955, it is expected that 1,000 technical personnel will be employed. The cost of operation of the Center when completed is estimated to be between $9,000,000 and $10,000,000 per year.

Currently planned and under study are three major facilities—a high-altitude engine-test facility, a gas dynamics facility, and a large supersonic wind tunnel. The engine-test facility is intended for the testing and development of ram-jet, turbojet, and associated power plants. Atmospheric conditions at any altitude, including temperature variations from −120° to +680°F., can be simulated. The supersonic tunnel will be capable of operating at Mach Numbers exceeding 3. Full-scale jet engines and, in some cases, complete jet-engine installations will be accommodated. The gas dynamics facility will operate at Mach Numbers greater than 5. This facility will be used primarily for testing missile and aircraft components.

▸ **Aerial Photography**—Colonel Goddard's talk included a brief history of aerial photography from the time an early aerial photograph of Boston was taken from a balloon, through the First and Second World Wars, and up to the present. His talk was accompanied by slides illustrating techniques and equipment and included the showing of three-dimensional kodacolor panoramic pictures taken close to the ground in high-speed flight.

Colonel Goddard called attention to the expanding needs and requirements of aerial photography and the accompanying research and development work entailed in bringing into being the specialized camera and auxiliary components needed. Current requirements shaping research and development programs are concerned with problems of high-altitude photography, "close-in" high-speed photography, night photography, gunnery-run photography, and such techniques as required to detect camouflaged areas.

Colonel Goddard described the cameras used in the Republic Rainbow airplane that traversed the country from the west to the east coast in a little over 6 hours, taking a continuous series of photographs 400 miles wide. He pointed out that through the use of equipment similar to this, the United States could be photographed in six passes. New cameras under development include one employing a 40-in. lens (F6.3) and another employing a 240-in. lens (F10). This latter camera could be used to take oblique photographs of a target from a distance of approximately 60 miles. The equipment is estimated to weigh about 3,000 lbs. and would be used in a B-36.

Among other recent developments, Colonel Goddard referred to a camera that renders three-dimensional scenes in color. These photographs have proved useful for detailed briefing work and battle-damage evaluation.

I.A.S. MEMBERS TRAIN BOY SCOUTS

The San Diego Section, in cooperation with the local Boy Scouts, organized an introductory aviation course for Explorer Scouts. The faculty for this civic project, composed entirely of I.A.S. members of the Section, are all experts in those subjects on which they lectured. Fifty-seven Boy Scouts satisfactorily completed the course and received the Explorer Scout Aviation Award. The curriculum included: Introduction to Aviation, Model Airplanes, Aerodynamics, Aircraft Structures, Power Plants, Airplane Design, Primary Flight Training, Instruments, and Meteorology and Navigation. Requirements for the award are (1) good attendance, (2) construction of a flying model airplane, and (3) passing a final examination. Consolidated Vultee Aircraft Corporation provided a meeting room at their plant, although one of the nine sessions was held at the San Diego Vocational School.

Student Branches

Academy of Aeronautics

A color film, *The A B C's of G*, was shown at the June 14 meeting. The picture, a C.A.A. release using Navy personnel and equipment, was concerned with the effects of gravity on the pilot and airplane. Chairman Thomas Buckley presided; 40 persons attended.

On June 28, a color motion picture, *Utility Unlimited*, released by Bell Aircraft Corporation, was presented to the 41 attenders. It illustrated the use of helicopters in several different industries. Chairman Buckley presided.

Tornado in a Box was the title of the film shown at the July 12 meeting. An Allis-Chalmers Manufacturing Company production, it explained the theoretical, as well as the practical, application of the gas turbine. Chairman Buckley presided; 50 persons attended.

The following officers were elected: Chairman, James Sneden; Vice-Chairman, Bernard Buc; Secretary, Arthur Runyan; Corresponding Secretary, John Mako; Treasurer, Anthony Martellucci; and Sergeant-at-Arms, Robert White.

Cal-Aero Technical Institute

On July 10, the speaker was Robert Hardy, a recent graduate of Cal-Aero Tech., who spoke on "Photo Elastic Analysis." Mr. Hardy outlined the development and use of this system in testing and analyzing.

Chairman John U. Sweeney presided; 50 persons attended.

University of Cincinnati

At the June 26 meeting, William Purdy, Project Engineer, The Glenn L. Martin Company, spoke on the "Viking Rocket and Gorgon Missile." Martin films that depicted the rocket and missile were shown to the 50 attending persons. Chairman Rader O. Hale presided

Members Elected

The following applicants for membership or applicants for change of previous grades have been admitted since the publication of the list in the last issue of the REVIEW.

Elected to Associate Fellow Grade

Frise, L. G., Chief Engineer and Designer, Percival Aircraft, Ltd.

Elected to MEMBER Grade

Allison, Lawrence M., B.S.M.E., Senior Project Engineer, Boeing Airplane Co. (Wichita).

Bifano, Michael, B. of Ae.E., Senior Engineer, Project and Design, Allison Div., General Motors Corp.

Farrar, Earl V., M.E., Asst. Chief Engineer, Wright Aeronautical Corp. Div., Curtiss-Wright Corp.

Miller, Mason F., S.M. in E.E., Aero. Research Scientist, N.A.C.A., Langley Air Force Base.

Moore, John R., B.S.M.E., Group Leader, Electromechanical Group, Aerophysics Lab., North American Aviation, Inc.

Mundt, Kenneth F., A.B. in E., Manager of Engineering and Manufacturing, Aerojet Engineering Corp.

Phillips, Aris, Dr. Ing., Acting Asst. Professor, Stanford University.

Rogers, John M., M.E., Consultant, Douglas Aircraft Co., Inc. (Santa Monica).

Shipp, J. C. K., B.S., West Coast Representative, British Joint Services Mission.

Webber, C. H., B.S., Manager, Aero. Div., Pacific Scientific Co.

Wood, William W., Jr., B.S.E.E., Chief Engineer, Link Aviation, Inc.

Transferred to MEMBER Grade

Anderson, Benjamin M., B.A., President, Anderson, Greenwood and Co.

Comisarow, Paul, B.S. in Ae.E., Aero. Engineer GS-11, Bureau of Aeronautics, Department of the Navy.

Elected to Technical Member Grade

Ali, Sheikh Mukarram, B.Sc. (Eng.), Pilot Officer in Technical Branch, Royal Pakistan Air Force.

Belle, J. M., Graduate of École Superieure d'Aeronautique, Asst. to Chief Aerodynamicist and Liaison Engineer in United States, Breguet Aircraft (France).

Durand, Jack A., B.S. in Ae.E., Instructor in Aero. Engineering and Mathematics, Parks College of St. Louis University.

Syne, Tobias, Ing. (M.E.), Major, Israel Air Force.

Transferred to Technical Member Grade

Abar, Frank H., Jr., B.S. in Ae.E.

Abramson, Andrew E., M.S., Aero. Research Scientist, N.A.C.A. (Cleveland)

Adams, Loyd A., B.S., Crop Dusting Pilot, Blytheville Flying Service.

Allsup, John R., Jr., B.S. in Ae.E., Jr. Engineer "B," Boeing Airplane Co. (Seattle).

Anderson, Kenneth F., B.S.Ae.E., Engineering Draftsman "B," North American Aviation, Inc.

Arabian, Donald D., B.S., Aero. Research Scientist, N.A.C.A., Langley Air Force Base.

Axtell, Howard W., B.S. in Ae.E., Engineering Draftsman, North American Aviation, Inc.

Banche, Joe F., B.S. in Ae.E., Student, University of Illinois.

Battis, William S., Draftsman, Lockheed Aircraft Corp.

Beadling, John D.

Beckwith, Walter C., III, Sc.M.

Bennett, George J., B.S.M.E. (Aero.).

Berglund, Lawrence O., Major and Aircraft Maintenance Officer, U.S.A.F., Wright-Patterson Air Force Base.

Bernstein, Stanley, B.Ae.E., Research Asst., Polytechnic Institute of Brooklyn.

Bertini, Euclid P., B.S. in Aero.; B.S. in Industrial Engineering, Tool Designer, General Motors Corp.

Bjornestad, Halvor, B.A.Sc., 1st Lt., Royal Norwegian Air Force, Technical Branch; assigned as Control Officer at Kjeller Aircraft Factory.

Blain, C. Wilfred, B.A.Sc., Specialist Officer, Aero. Engineering Branch, Air Materiel Command, Royal Canadian Air Force.

Blom, Niels A. J., B.A.Sc., Postgraduate Student, University of Toronto.

Bloom, Donald E., B. of Ae.E., Design Engineer-Trainee, Consolidated Vultee Aircraft Corp. (Fort Worth).

Boll, Robert T., B.S., Jr. Engineer, Boeing Airplane Co. (Seattle).

Brabson, William H., Jr., M.S.E., Capt., U.S. Army; Aero. Engineer and Pilot (Light Aviation), A.A.F., Bd. No. 1 (Fort Bragg).

Bradfield, James, B.S.

Brill, Murray A., B.A.E.

Brown, Donald G., B.S.Ae.E.

Brown, R. A., M.S. in Ae.E.

Burch, Reed L., B.S. in Ae.E., Engineer, Boeing Airplane Co. (Seattle).

Calhoun, John D., B.S., Capt. and Pilot, U.S.A.F.; Student, U.S.A.F. Institute of Technology, Wright-Patterson Air Force Base.

Campbell, Francis W., B.S.E.E., Major and Project Officer, U.S.A.F., Wright-Patterson Air Force Base.

Carnavos, Theodore C., B. of Ae.E.

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Cohen, Nathaniel B., B. of Ae.E.

Cook, Everett L., A.A. in A.E., Draftsman and Detail Designer, Technical Training Aids, Inc.

Cooper, Bernard, B. of Ae.E.

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DePuy, Ivan W., B.S. in Engineering, Structures Engineer, Bell Aircraft Corp.

Dickinson, Charles W., B.S. in Aero., Structural Aero. Engineer, Boeing Airplane Co. (Seattle).

Dotson, Herbert F., Jr., B.S., Capt. and Sr. Pilot, U.S.A.F.; Research and Development Project Officer, Wright-Patterson Air Force Base.

Drake, William M., B.S. in M.E., Flight Instructor, North American Flying Service, Inc.

Dryer, Murray, M.S. in M.E. (Aero.).

Dunham, James W., M.S. in Engineering, Capt. and Guided Missiles Officer, U.S. Army; assigned to the Department of Physics and Chemistry, U.S. Military Academy (West Point).

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Eisenberg, Bernard L., B. of Ae.E.

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Ericson, Donald M., B.Ae.E., Field Engineer, Minneapolis-Honeywell Regulator Co.

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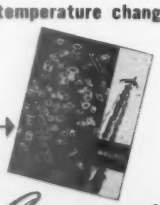

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Semcken, John H., Jr., B. of Ae.E.

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Stewart, John D., B.S.

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Wrong, Colin B., B.A.Sc., Engineer, Gas Turbine Div., A. V. Roe Canada Ltd. (Malton).

Yarrington, Paul D., A.A. in Ae.E., Engineering Draftsman, Hughes Aircraft Co.

Young, John W., Jr., B.M.E., Capt., U.S.A.F.; Research and Development Officer, Air Proving Ground, Hq. and Hq. Sq., Eglin Air Force Base.

Young, Robert W., B.S.M.E.

Aeronautical Reviews

(*Continued from page 74*)

Derivation, within the scope of linear airfoil theory, of the values, corrected for the presence of the wind-tunnel wall, for lift, total moment, aileron hinge moment, and tab hinge moment of an oscillating airfoil, expressed as function of the ratio of the wing chord to tunnel height and as a function of the reduced frequency.

The Effect of Wind Tunnel Fan on Irregularities in the Velocity Distribution. J. H. Preston. *Gt. Brit., Aeronautical Research Council, Reports and Memoranda No. 2307,* 1950 (September, 1944). 4 pp. 3 references. British Information Services, New York. $0.30.

A wind-tunnel fan in common with a gauze always tends to reduce the deviations of velocity in the stream passing through it. By proper design of the fan and its correct placement in the return circuit, a windmill can be dispensed with, and the number of smoothing screens reduced with a consequent saving in power.

Development and Preliminary Investigation of a Method of Obtaining Hypersonic Aerodynamic Data by Firing Models Through Highly Cooled Gases. Harold V. Soule and Alexander P. Sabol. *U.S., N.A.C.A., Technical Note No. 2120,* July, 1950. 38 pp., illus. 8 references.

Some Remarks About High-Frequency Rotary-Current Electric Motors for Driving Model Propellers. J. G. Slotboom. *Netherlands, Nationaal Luchtvaartlaboratorium, Report No. A.1011* (*Verslagen en Verhandelingen*, Vol. 13, pp. A9–A11), 1947, 3 pp., illus. (In English.)

Tunnel Gives Mach 9 Test Speeds. *Aviation Week,* Vol. 53, No. 3, July 17, 1950, p. 15, illus. The N.A.C.A. Supersonic free-flight wind tunnel, Ames Aeronautical Laboratory, Moffett Field, Calif.

Comparison of Results of Tests in the N.A.C.A., R.A.E. and N.R.C. Spinning Tunnels. L. T. Conlin. *Canada, National Research Council, Division of Mechanical Engineering, Report No. MA-221,* March 7, 1950. 13 pp., illus.

Design of a Schlieren Optical System. James H. Brown. *Washington, University, Engineering Experiment Station, Research Project No. 34, Report No. 304 A,* August, 1949. 58 pp., illus. 8 references. $4.00.

Basic theory, preliminary design, and layout of a schlieren system built for the 3- × 3-in. low-density supersonic wind tunnel at the University of Washington. The instrument uses a General Electric BH-6 lamp, a 6 in. parabolic mirror that is correct to $^1/_{10}$ wave length sodium "D" lines with a focal length of 8 ft., and a 6 in. plane also correct to $^1/_{10}$ wave length. A small half-silvered mirror allows the light going out from the lamp to be separated from the light returning to the camera but permits absolute coincidence and hence eliminates a double image.

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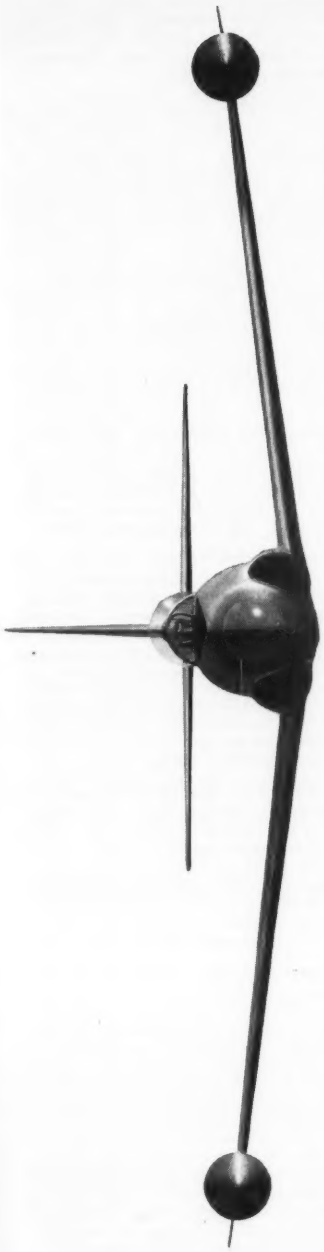

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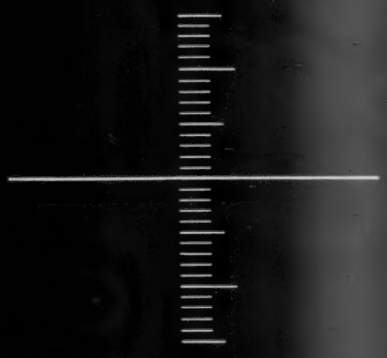

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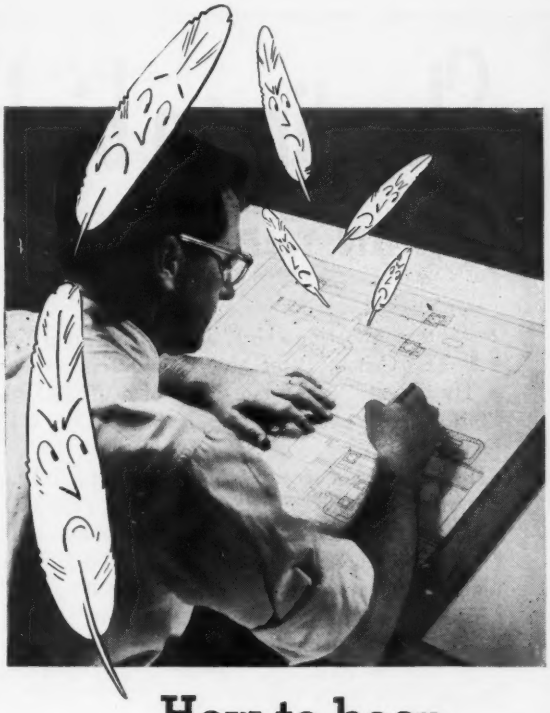

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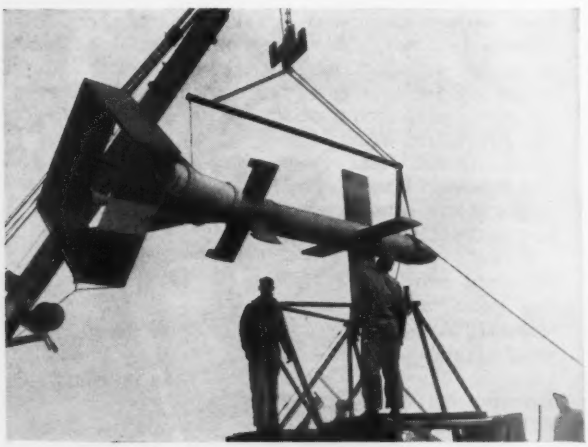

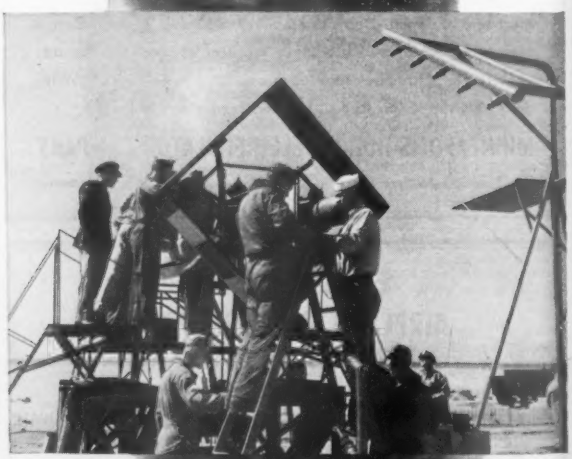

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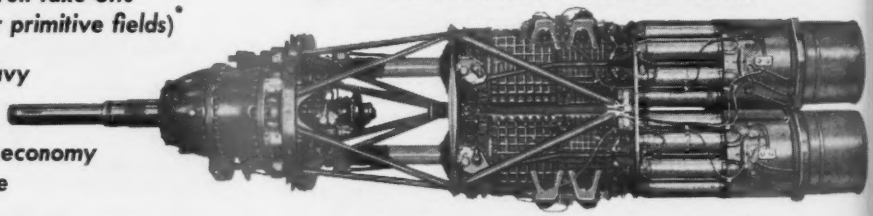

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